THE UNIVERSITY OF ALBERTA

A MICROMORPHOLOGICAL INVESTIGATION ON THE GENESIS OF SOILS DEVELOPED ON CALCAREOUS AEOLIAN MATERIAL

by

© JULIAN DUMANSKI, B.S.A., M.SC.

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "A micromorphological investigation on the genesis of soils developed on calcareous aeolian material" submitted by Julian Dumanski, B.S.A., M.Sc., in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

ABSTRACT

Classical theories in soil genesis have assumed that horizon differentiation in calcareous material must be preceded by decarbonation and decalcification. However, in the Hinton area of Alberta there are soils developed on aeolian materials which have horizon sequences indicative of translocation of both hydrated iron oxides and clay, but with free lime carbonates and alkaline reactions throughout the solum. Such soils also have prominent Ahk horizons. This study was initiated to locate these soils in terms of their areal distribution, to characterize them for purposes of soil classification, and to study their genesis.

Initially, the area was mapped at a scale of 1 inch = 1 mile, after which representative sites were sampled for soil characterization and classification. The results indicated that these soils could be accommodated in the Canadian soil classification scheme through the use of the adjectives "Calcareous" and "Moder" where appropriate.

Soil monoliths were sampled for studies of soil genesis, utilizing the detailed approaches of soil micromorphology. The monoliths were subdivided into 2 - 3 inch subhorizons after which duplicate thin sections were made of each subhorizon. Micromorphological observations were quantified through the application of modal analysis. The remaining material of each subhorizon was bulked and used for routine characterization studies, clay mineralogical studies, and free grain, petrographic analyses of the fine sand fraction. Results were related to individual soil microfabrics and analysed statistically using Duncan's New Multiple Range test.

Four fabric types were recognized in the soils studied and their

distribution was found to be closely associated with particular soil horizons. Experimental micromorphology indicated that the fabrics were a function of both the materials present in the fabrics and the soil processes peculiar to a particular soil horizon.

A summation of all observations made during the study facilitated the postulation of a theory on the historical development of the soils. Free grain, petrographic analyses of the fine sand fraction indicated a hiatus in loessial deposition of sufficient time to allow for the development of a distinct, reddish brown "paleo" B horizon. Subsequent excessive burial in regions contiguous to the loess source preserved this horizon *in situ*. In other areas, where burial had been less than about 10 inches, recent pedogenic processes acting on the "paleo" B horizon resulted in the internal translocation of both clay and hydrated iron oxides. This was visualized as being the result of lessivage processes in the "paleo" B horizon, promoted through the concentration of secondary lime carbonates into discrete, local microareas.

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This manuscript is dedicated to the author's late wife, Margaret. It was completed under the inspiration derived from her memory.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF PLATES

INTRODUCTION

A classical assumption has been that in the genesis of soils containing argillic horizons, clay illuviation must be preceded by decalcification. However, for many years it has been known that in the Hinton region of Alberta there were pedologically interesting soils that showed both Brunisolic Gray Luvisol morphologies and the presence of calcium carbonate throughout the solum as detected with dilute hydrochloric acid. Although these soils had not previously been studied, it was suspected that they were developed in post-Pleistocene aeolian deposits. This study was undertaken to determine the areal distribution of the soils concerned, to characterize them for classification purposes, and to study their genetic development.

The three fold objective of the study necessitated both field and laboratory work. The area was mapped at a scale of 1 inch = 1 mile, taking into account profile morphology, soil textures, thickness of loessial overlay, topography, and drainage. Upon completion of the mapping phase, selected profiles were sampled in replicate for purposes of soil characterization. The final phase of the field work was the sampling of typical monoliths to be used for detailed soil genesis studies, with emphasis on soil micromorphology. This approach was selected above others because of the ability of the technique to indicate not only the character of the genetic processes responsible for soil development, but also the type of research necessary to substantiate the inferred processes.

PHYSIOGRAPHY OF THE AREA

Location

The area under study is located within the boundaries of Alberta

map sheet 83 F. It is entirely confined by 53° 10' and 53° 20' north latitude, and by 117° 25' and 117° 55' west longitude. Within the specified area the study was limited to those soils which show visible effervescence with dilute hydrochloric acid throughout the solum. The area is diagrammatically shown in Fig. 1 and represents a total of approximately 98,300 acres.

Geology and Topography

Soil genesis in the study area is affected by the underlying geology, glacial processes, and post glacial aeolian deposition. Roed (1968) reports bedrock in the vicinity of Hinton to be composed of a thick sequence of clastic rocks belonging mostly to the Brazeau Formation. These rocks are of Late Cretaceous age. The Front Ranges of the Rocky Mountains west of the study area are composed of carbonate, argillaceous, and arenaceous rocks of Devonian to Permian age (Mountjoy, 1962).

Bedrock is commonly overlain by Obed till (Roed, 1968) within the confines of the Athabasca valley. This is a very cobbly, olive brown to olive black colored till, with medium to coarse texture, and contains 18 to 30 per cent carbonates. Thickness of the till varies from several feet to 145 feet, but the average thickness is approximately 15 feet. Pebble lithologies are such as to suggest that the Front and Main Ranges of the Rocky Mountains contributed most to the debris of the Obed glacier.

Obed till is usually overlain everywhere by post-glacial deposits. There are two large, paired, outwash terraces commonly called the Hinton terraces (Stene, 1966), in regions contiguous to the Athabasca River. These occur at elevations of approximately 100 and 200 feet

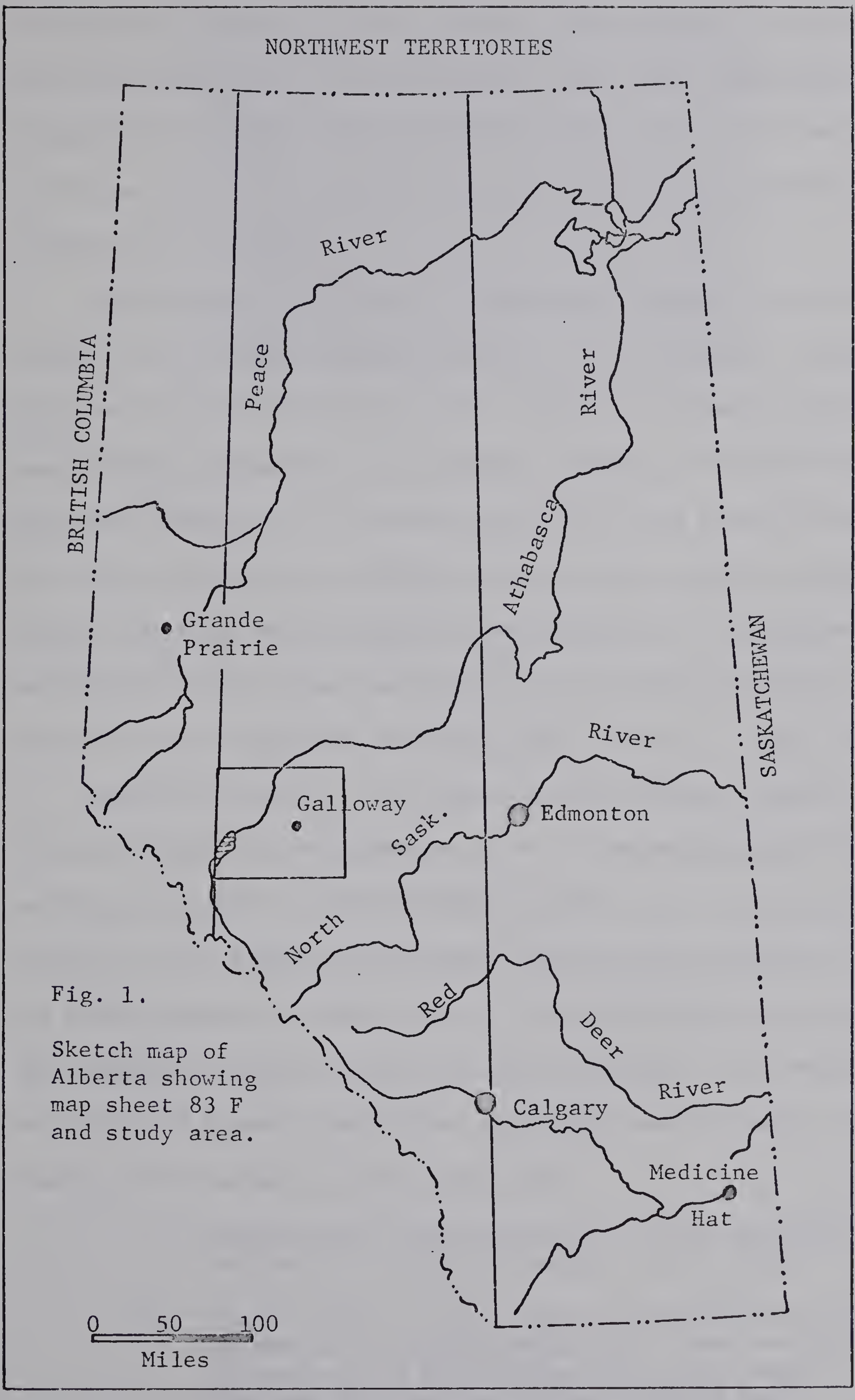

Fig. 1.

Sketch map of Alberta showing map sheet 83 F and study area.

above present river level, both contain appreciable quantities of cobbles and pebbles, and both exhibit cross bedding. Concomitant with the deposition of terrace gravels there were depositions of lacustrine silts and clays in several local areas. In some cases these may represent old oxbow lakes; in other cases they may have formed by ice damming.

Superimposed on all the aforementioned deposits is an extensive blanket of calcareous aeolian material. This material is generally grayish brown (2.5Y 5/2)* in color, friable to loose in consistence, and strongly calcareous. It commonly consists of a mixture of silt and very fine sand, with varying amounts of both finer and coarser particles. It is up to 200 feet thick in the vicinity of Brulé Lake (Roed, 1968) but thins rapidly towards the east. Elevational extremities of the loess material range from about 4,700 feet a.s.l. near the source region**, to about 4,000 feet a.s.l. east of Hinton.

Aeolian activity at the present time is common along the braided channel of the Athabasca River in Jasper National Park, as well as along the shores of Brulé Lake (see Plate 1). This activity results in the formation of elongate blowouts and parabolic (?) dunes in areas adjacent to these sources, but stabilization by vegetation has generally curtailed active erosion elsewhere. The eastern extremity of loessial deposition is located near Galloway, approximately 25 miles east of the study area.

* Munsell soil color notation. Unless otherwise stated, all colors are moist, field colors.

** Source region in all cases mentioned refers to the source of the aeolian material. These are the floodplains of the Athabasca River in Jasper National Park and the shores of Brulé Lake, which have elevations of 3300 - 3200 feet a.s.l.

Plate 1. South end of Brulé Lake at low water level, showing exposure of alluvial sands and silts.

The topographic cross-sections accompanying the soils map, indicate that topography in this area is very complex. The Athabasca River valley is a broad regional depression, ranging from 10 to 14 miles in width. The valley walls show evidence of extensive erosion before the advent of glaciation. In turn, glaciation modified the existing dissected landforms by superimposing various erosional and depositional features. These include flutings, grooves, drumlins, "circles", various till moraines, and kame moraines. Finally, the entire region is covered by a blanket of loess which in most cases is too thin to mask the underlying topography, but modifies it slightly through the formation of local erosion pits, sand shadows, etc. In the region east of Brulé Lake, however, the loess is of sufficient thickness to mask all except the most dramatic topographic features. In this region typical dune topography prevails.

Vegetation

The study area occurs in the Boreal-Cordilleran phytogeographic

region (Moss, 1955). The most common tree species on well drained, upland sites are associations between aspen (Populus tremuloides) and white spruce (Picea glauca). Lodgepole pine (Pinus contorta var. latifolia) occurs sporadically throughout the region but is not as common as white spruce or aspen. Local, poorly drained depressions are usually covered by stands of black spruce (Picea mariana) in association with white spruce and balsam poplar (Populus balsamifera).

Undergrowth species are highly variable. In general, they consist of a predominance of feathermosses, bearberry (Arctostaphylos uva-ursi), bog cranberry (Vaccinium sp.), buffalo berry (Shepherdia canadensis), juniper (Juniperus spp.), grasses (Agropyron sp.), and various herbs (e.g. Carex sp.). Poorly drained depressions are most commonly occupied by feathermosses, but in isolated cases, sedges appear to dominate.

The dissemination of calcareous, aeolian material from the source eastward appears to result in a geographic zonation of carbonate content, sand content and soil reaction. Undergrowth distribution varies in accordance with this from a grass - wild rose (Rosa sp.) association in areas near the source, to a buffalo berry - bearberry - feathermoss association in eastern portions of the area. In regions beyond the influence of calcareous loess, where soil reaction has regionally become slightly or moderately acid, buffalo berry disappears entirely, and feathermoss - bearberry predominate. For similar reasons, the incidence of aspen decreases drastically, while alpine fir (Abies lasiocarpa) becomes more common.

The alkaline reaction throughout the soil profile (caused by an abundance of carbonates) and the very high percentage of the cation exchange complex occupied by calcium appear to adversely affect spruce

growth in the region. Trees commonly appear to be rather stunted, possess a dense branching habit, and show a characteristic reddening at the tips of the needles. These calcareous soil areas are also problematic in terms of juvenile tree growth (D.I. Crossley, personal communication).

Climate

The study area experiences a subhumid, continental climate with moderate precipitation, because it is located east of and immediately adjacent to the mountains. Winters are long and cold, while summers are mild (Fig. 2). Mean annual precipitation at Entrance is approximately 20 inches with about 72 per cent of this falling as rain. This compares favourably with Edson (20.8 inches of precipitation with 72 per cent as rain), but is in contrast to Jasper, which receives about 16 inches of precipitation of which about 68 per cent is rain. Temperature ranges from 59°F in July to 11°F in January, with a mean annual temperature of 37°F. The frost-free period at Entrance is about 42 days.

LITERATURE REVIEW

Genesis of Forested Soils on Calcareous Parent Material

Soils which have developed on calcareous parent materials occur throughout the cool and warm temperate regions of the world. Such soils are very diverse in their morphologies and properties, but their early stages of development are always characterized by the synchronous processes of decarbonation, decalcification, and lessivage (Duchaufour, 1965). Soils formed under forest vegetation in cool temperate climatic regions of Europe undergo pedogenic development somewhat similar to that observed in the study area.

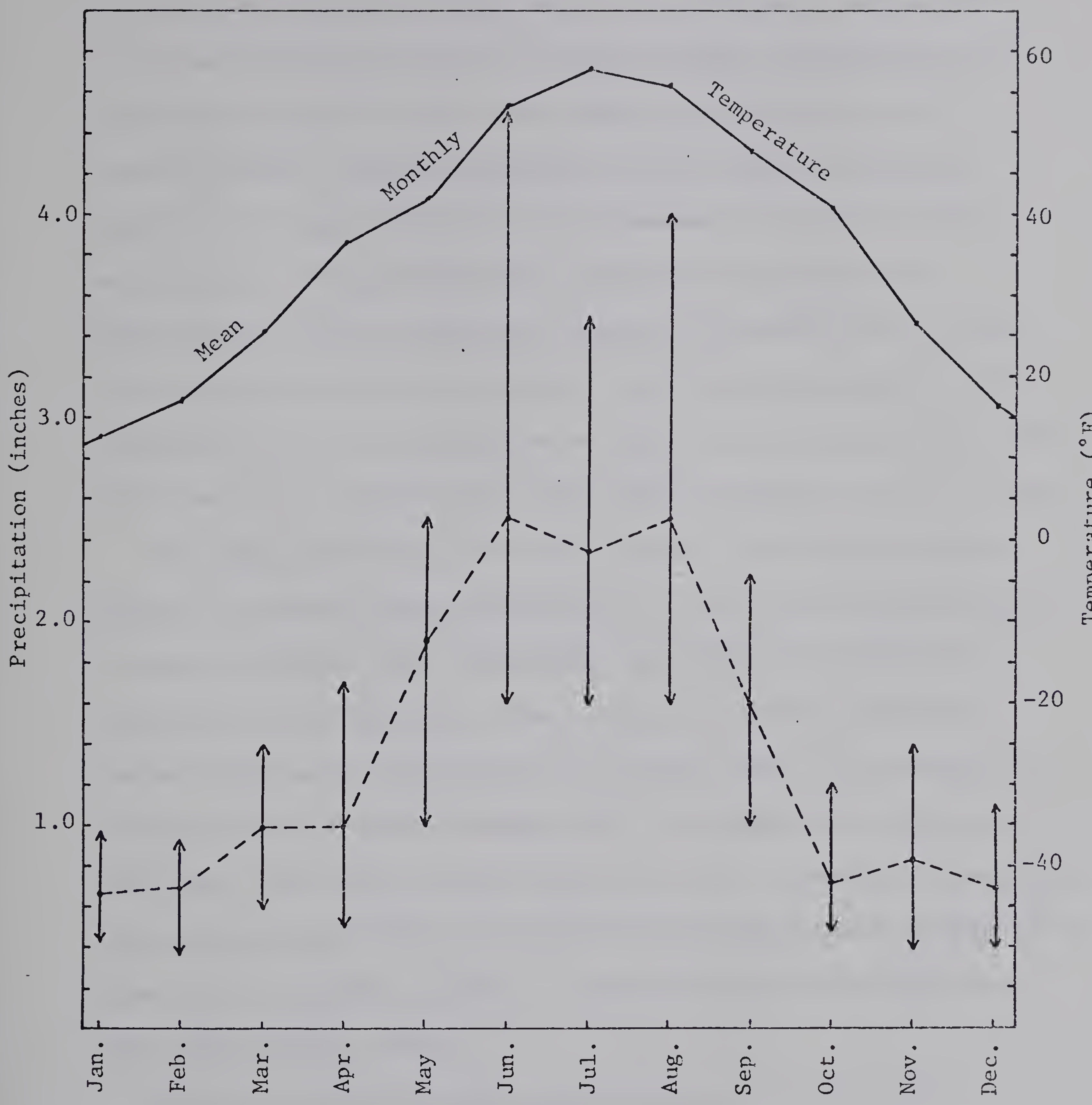

Fig. 2. Quartile precipitation probabilities and mean monthly temperatures for Entrance, Alberta. Data collected over the past 41 - 47 years (Department of Transport, Toronto).

Soils developed on high lime materials (marl, chalk, limestone, and calcareous loess) in Europe are called Rendzinas. Such soils have an extreme diversity of form but all have profiles characterized by a sequence of Ah Ck horizons, and usually by high stone contents (Kubiena, 1953). Chemical weathering and lessivage are strongly impeded by the lime during the early pedogenesis on such materials, and therefore, only the process of decarbonation is operative. Simultaneously, there is mixing of organic and mineral matter in the form of animal droppings, resulting in the formation of moder or mull Ah horizons. Soil reaction may be as high as pH 8.0 (Duchaufour, 1965). Equivalent soils in Canada are called Cumulic Regosols (N.S.S.C., 1968).

The pH of the surface soil drops to 6.5 - 7.0 as excess lime is gradually removed by percolating waters, in which case surface horizons no longer effervesce with dilute HCl. Decarbonation is gradually succeeded by decalcification. The strength of chemical weathering gradually increases, promoting clay enrichment due to the precipitation of free ferric hydroxide (Kubiena, 1953). Consequently, transitional soils occur with profile types A (B) C or A B C. These are called Brown Rendzinas (Kubiena, 1953), Braunified Darkened Rendzinas and Calcareous Brown Soils (Duchaufour, 1965), or Degraded Rendzinas and Calcareous Brown Soils (Aubert, 1968).

Continued decalcification, and the gradual initiation of lessivage and associated processes, leads to an intensification in the development of a B horizon. In cool, humid climates iron becomes complexed by organic substances and is leached downward, forming a finely flocculated, brown plasma and a Bm horizon (Kubiena, 1953; Papadakis, 1964). In some instances iron-organic matter nodules may

precipitate on clay surfaces (Pawluk and Lindsay, 1964). Such soils are called Brown Forest, and Leached Brown Soils (Duchaufour, 1965), Brown Earths (Kubiena, 1953), and Isohumic Brown Soils (Aubert, 1968). Canadian equivalents are Melanic Brunisols and Eutric Brunisols (N.S.S.C., 1968). With the passage of time or an intensification of the processes, these soils, which formed under the effects of braunification, could become subject to true lessivage and/or podzolization (Zonn, 1966). The end result would then be Sols Lessivé (Brown Podzolics), Sols Lessivé Podzolique (Gray Luvisols) and/or Podzol soils.

Soils Common to Foothills Regions

Although soils information for foothill environments is relatively scarce, present indications are that such soils are rather similar to those found in the Gray Wooded areas of the Northern Great Plains (Odynsky, 1962). Thus, Beke (1969) describes Gray Luvisols (Gray Wooded), Eutric Brunisols, Dystric Brunisols, Black and Dark Gray Chernozems, and Regosols as part of the soil pattern in the Deer Creek watershed. He notes, however, the difficulties involved with accommodating the observed Chernozems within the Chernozemic Order (N.S.S.C., 1968) because of the moder character of the Ah horizon. He further states that although the Gray Luvisols are morphologically similar to those of the plains, they are usually slightly base unsaturated (ammonium acetate procedure), contain appreciable amounts of kaolinite in the solum, and generally fail to show any significant amounts of organic matter accumulation in B horizons.

Lindsay, Wynnyk and Odynsky (1963) described the presence of Gray Luvisols, Bisequa Gray Luvisols, Eutric Brunisols, and Orthic Podzols

in the foothills region of map sheets 83 F and 83 L. They reported that soil reaction within the solum ranged between 4.8 and 6.0, with base saturation ranging between 42 per cent and 82 per cent. Analytical results indicated the presence of sufficient clay illuviation in Luvisolic soils to meet the criteria for argillic horizons (Soil Survey Staff, 1960) but the authors failed to mention the presence of significant amounts of cutanic accumulations in Bt horizons even though structural development was fairly distinct.

In summary, the limited information indicates that foothill soils are morphologically similar to those of the plains but tend to be base unsaturated and more acid in reaction. Luvisolic soils show only patchy and irregular cutans. Corresponding soils on the plains by contrast tend to be almost completely base saturated, and acid to weakly acid in reaction. They exhibit strongly expressed, thick, continuous cutans (Pawluk, 1961; St. Arnaud and Whiteside, 1964).

In the exploratory survey of Alberta map sheets 83 L, 83 K, 83 F, and 83 J, Lindsay, Wynnyk and Odynsky (1963) described a region in the following manner:

> "Along Highway 16 from the National Park boundary to about Galloway the area is floored with a grayish colored, calcareous, gravelly outwash. This material is often overlain with a relatively thin cover of sandy, alluvial material..."

Lindsay (1966), in writing about Brunisolic Gray Luvisols as well as other soils in the Hinton area, stated that the soils

> "are moderately to strongly alkaline throughout the sola. Such a feature is not generally associated with this type of soil development and the reason for the strong alkaline reaction is not understood. A further study of this characteristic is clearly required."

Roed (1968) later characterized the gravelly "outwash" as Obed till,

and recognized the overlying materials as aeolian deposits. Soils developed in these aeolian deposits were ones on which this study was conducted.

Micromorphology and its Application to Studies in Soil Genesis

Webster (1967) defines "genesis" as the origin, or coming into being of something. In terms of soil, then, genesis refers to the multifarious processes and influences which result in a soil of distinctive morphology, character and properties.

Although many possible avenues for investigating the genesis of a particular soil have been used, not all yield comparable results especially within a limited time. The classical approach has been to systematically differentiate bulked soil samples into particular fractions and then to resolve the composition of the fractions, with the ultimate aim of resynthesizing the various components into a developed soil. Kubiena (1964) stated that this approach would never reveal the characteristics of an undisturbed soil, with its multiplicity of microscopic structures, but would only deal with little piles of debris. He claimed that studies of this type, although serving a useful function for a particular purpose, are merely studies of substance.

Micromorphology on the other hand, deals with both substance and form, in that it not only attempts to identify the various components of a soil, but also endeavors to describe the arrangement of the components in relation to each other. At the same time it attempts to elucidate hypotheses as to the origins of such microstructures (Kubiena, 1964). Micromorphology, therefore, keeps in constant touch with reality, avoids the danger of incorrect synthesis, and permits

one to assign proper significance to data (Yarilova, 1963).

For all its advantages, however, micromorphology is only a technique. Fedoroff (1968) lists its general position in the ensemble of pedology, and indicates the complimentary nature of data obtained in this manner to that obtained by classical, chemical, and physical means. The object of micromorphological studies is the soil in its natural, undisturbed state (Yarilova, 1963). The micromorphologist considers all elements of the soil in their interrelationships, attempts to define the most important elements among them, and tries to explain the role of each. Consequently, the soil becomes not a heterogeneous mixture of component parts but a complex of microstructures composed of multifarious although characteristic elements (Kubiena, 1964).

Soil materials are composed of two broad groups of constituents that have distinctly different properties. The first of these, called "skeleton", consists of mineral grains and resistant siliceous and organic bodies larger than colloidal size; the second, referred to as "plasma", includes all mineral and organic material of colloidal size or smaller (Kubiena, 1938; Brewer, 1964b). Materials of the first group are relatively stable, while those of the latter are capable of remarkable movement, concentration, and reorganization under the influence of pedogenic processes (Brewer, 1964a). "Fabric" refers specifically to the spatial arrangement of soil constituents and associated voids (Brewer, 1964b).

Reorganization of constituents within the soil system during pedogenesis often promotes the formation of discrete bodies called "pedological features". Brewer and Sleeman (1960) defined this term as:

> recognizable units within a soil material which are distinguishable from the enclosing material for any reason, such as origin, change in concentration of some fraction of the plasma, or change in arrangement of the constituents.

Many pedological features have been recognized and described. These include: cutans, pedotubules, glaebules, crystallaria, subcutanic features, and fecal pellets (Brewer, 1964b). All such features owe their origin to translocation of plasmic materials, in situ re-organization of plasmic materials, or biologic activity.

The organization of soil plasma constitutes a characteristic reflection of soil process since its structure is primarily affected by specific features of soil environment (Dumanski, 1970). Therefore, by comparing the fabric of a soil to that of its parent material, the kinds of soil-forming processes that have been operative can be directly inferred if sufficient background information is available (Brewer, 1964b). The derivation of such hypotheses, based on logical inference and on known properties of the constituents involved, provides a basis for experimental work intended to reproduce phenomena observable in soil material. This technique was followed by Buol and Hole (1961), and by Brewer and Haldane (1957) in studies designed to reproduce cutans, and by Dumanski (1964) in development of Ae horizons and platy structures. The results of such experiments play an important part in elucidating the dynamics of soil formation and the processes that occur within the soil body (Osmond, 1958).

Although past work in soil micromorphology has been essentially descriptive, recent developments have revealed an emphasis on quantitative micromorphological observations. Since this aspect is still not fully developed, most workers have concentrated on techniques

adopted from the science of Petrology. In this regard, Anderson and Binnie (1961), Milfred, Hole and Torrie (1967), and Brewer (1968) applied the concept of modal analysis to soil micromorphological analysis. McKeague, Bourbeau and Cann (1967) estimated percentages of oriented clays with the aid of an ocular grid. A semi-quantitative estimation of the occurrence of various fabrics common in eluviated horizons was reported by Dumanski and St. Arnaud (1966), utilizing the principle of presence or absence of a specific fabric in a thin section. Sleeman (1964) employed visual estimates of the degree of development for specific features and grain counts for others, and plotted this against depth. In this way he established the presence of a hiatus in sedimentary deposition of sufficient time to allow for soil formation.

METHODS

Field Mapping

The study area was mapped as part of a general reconnaissance soil survey of the west half of Alberta map sheet 83 F. During the course of that survey, aeolian material was observed to occur in a generally narrow belt from Jasper National Park eastward to Galloway. Soils developed on such material had reactions ranging from about pH 8.5 in the western portions, to about pH 6.5 at the eastern extreme. At the same time the portion of the area from Jasper National Park to about four miles east of Hinton displayed visible effervescence throughout the solum when treated with dilute HCl. Studies were then concentrated in this latter region.

Several basic criteria were employed during the mapping of the soils to be studied. In the first case, only the most common soils

were included in the soil edits*; those with less than 20 per cent occurrence were omitted. Secondly, the presence of an Ahk horizon is concurrent to the region in which $CaCO_3$ occurs throughout the soil solum. However, the presence of an Ahk horizon was not considered in soil classification unless the thickness of such a horizon was greater than 2 inches. Thirdly, a distinct, strong brown to yellowish red, sandy Bmk horizon (hereafter referred to as "paleo" B horizon) is common throughout the entire area. This horizon, which may be of paleopedologic significance, is buried progressively deeper as one approaches Brulé Lake. When burial exceeded the arbitrary depth of 20 inches, the presence of this horizon was no longer considered in the classification of soils.

Compilation of the soils map was done in accordance with criteria set up by the National Soil Survey Committee of Canada (1965), and later revised in compliance with new standards established in 1968 (N.S.S.C., 1968). In the course of the survey observations were made on profile type, soil reaction, profile texture, horizon color, structure and thickness, topographic class, vegetation, thickness of aeolian deposit, and nature of underlying material. Individual soil series were grouped into natural mapping units according to the concept of soil associations (Moss, 1965). Associations of soils were shown on the final map as combinations of symbols containing dominant and subordinate soils, B horizon textures prevailing within mapped units, and dominant topographic classes. Access roads and trails used in the survey, and the location of sampling sites are shown in Fig. 3.

* A soil edit is a composite of the symbols put on an individual soil area in a soil map.

LEGEND

Approximate boundary of high lime area.
Highways and all-weather roads.
Trails and footpaths.
x Soil sampling sites.
Monolith sites.

Scale: 1 inch = 4 miles.

Fig. 3. Sketch map of study area showing access and soil sampling sites.

Upon completion of the field mapping, sites representative of individual soils were sampled for purposes of soil characterization and classification. Procedures employed for this purpose are outlined under "Routine Analysis on Bulk Samples" in a later section. Apart from this, monoliths were taken from carefully selected sites, dissected in the laboratory, and specific samples selected for detailed genesis studies. In addition, a sample of charcoal was taken for radioactive carbon dating. The charcoal was situated in the middle of the "paleo" Bmk horizon, and taken from a site 3/10 of a mile south of Pocahontas, at which point the "paleo" Bmk is buried at a depth of approximately 7 feet below the surface (see Plate 2).

Plate 2. Exposure of "paleo" B horizon and charcoal just south of Pocahontas.

Routine Analyses on Bulk Samples

Profiles representative of individual soils were sampled and analysed for purposes of soil characterization and classification. Analytical procedures used were as follows:

Total Nitrogen - Kjeldahl method of Jackson (1958), using a mixture of mercurous oxide, copper sulfate and potassium sulfate as a catalyst.

Reaction - Soil paste method of Doughty (1941), using a Coleman glass electrode.

$CaCO_3$ Equivalent - By use of the Smolik Calcimeter (Bascombe, 1961).

Organic Carbon - By difference between total carbon and inorganic carbon. Total carbon was determined by dry combustion using a Leco induction furnace.

Oxalate Extractable Iron and Aluminum - According to the procedure outlined by McKeague and Day (1966).

Citrate - Dithionite Extractable Iron and Aluminum - By the method of Mehra and Jackson (1959).

Particle Size Analyses - By the pipette method as outlined by Toogood and Peters (1953).

Detailed Analyses on Monolith Samples

Monoliths typical of selected soils were taken for detailed analysis. A total of four monoliths were selected, each representing a different pedon. The soils selected were a Calcareous Brunisolic Gray Luvisol, a Calcareous Brunisolic Moder Gray Brown Luvisol, a Calcareous Orthic Moder Melanic Brunisol, and a Calcareous Degraded Moder Melanic Brunisol.

After air-drying the monoliths in the laboratory, the soils were

described in detail. Each soil horizon was then sub-divided vertically into 2 to 3 inch sections, and duplicate, oriented clods were taken from each sub-horizon for micromorphological analysis. The remaining material of each sub-horizon was bulked, ground to pass a 2 mm sieve, and stored. These latter samples were used for analyses similar to those outlined under "Routine Analyses on Bulk Samples", and for mineralogical analyses.

Micromorphological Analyses

The oriented clods selected from the monoliths were impregnated using Castolite under vacuum, according to the general procedure outlined by Acton (1961). Each thin section was then described following the scheme outlined by Parfenova and Yarilova (1962), and employing terminology devised by Kubiena (1938) and by Brewer (1964b).

Modal Analysis

Petrographic descriptions of composition require both an identification of constituents and an estimate of their areal and/or volumetric proportions. Griffiths (1960) states that recognition of a constituent is rarely sufficient information to achieve most of the goals of petrographic analysis. He further claims that since complete identification is an impracticable ideal in most cases, it then becomes necessary to formulate procedures which represent the least possible compromise between "correct" identification and reasonably precise estimates of proportion. Therefore, it is necessary to define a set of mutually exclusive and readily identifiable classes, and then to classify the material by counting the frequency of each class according to a standard procedure.

With these principles in mind a point-count analysis was

conducted on each thin section. A total of 400 points per thin section were counted. These were made up of 8 randomly selected traverses of 50 points each, taken at right angles to any commonly observable, structural feature. Means and confidence limits were calculated for dominant classes in each thin section, and for the combination of duplicate thin sections, to yield data for each sub-horizon. This latter information was plotted against depth to give a volumetric expression of material distribution throughout the profile.

The constituents of each thin section were classified into twelve categories according to the following criteria:

Skeletal Material (grains greater than 10 μ)

(i) Quartz and feldspar - colorless, monocrystalline grains with uniform, patchy, parallel or cross-hatched extinction patterns. Relief and birefringence is low.

(ii) Primary calcite and dolomite - polycrystalline and monocrystalline grains with high pleochroism, high birefringence, and grain outlines indicative of partial weathering.

(iii) Primary siderite - dark gray to grayish brown, polycrystalline grains with high birefringence and weathered outlines. Often appears rather opaque in thin section.

(iv) Rock fragments - any constituent with a discernible boundary and anhedral shape which contains two or more minerals fused together. Cherts and volcanic fragments were included in this group.

(v) Others - any skeletal material unclassifiable into any of the other groups.

Plasmic Material (any material $<10\ \mu$ in diameter)

(i) Glaebules and iron nodules - sesquioxidic concentrations with spherical or irregular shapes, and recognizable as distinct from the rest of the soil matrix.

(ii) Free grain cutans - yellowish-brown optically oriented plasmic concentrations which partially or completely encircle skeletal grains.

(iii) Secondary carbonates - may be either cryptocrystalline carbonate accumulations of irregular shape, or colorless, monocrystalline carbonate crystals showing no effect of weathering.

(iv) Other - plasmic materials unclassifiable into any of the other groups. This may include both sepic and asepic plasmic material.

Pores

(i) Ortho pores - pressure, tension, and/or fracture voids without regular, coated outlines.

(ii) Meta pores - pressure, tension, and/or fracture voids with regular, coated outlines.

Organic Fragments

Reddish brown to black, irregularly shaped fragments which are opaque under crossed nicols.

Mineralogical Analysis

The bulked materials from each sub-horizon were fractionated according to the procedure of Kittrick and Hope (1963). Prior to centrifugal fractionation and concentration, carbonates were removed using sodium acetate buffered at pH 5.0, organic matter was oxidized using hydrogen

peroxide, and iron oxides were removed using sodium hydrosulfite. Both fine clay (<0.2 μ) and coarse clay (0.2 - 2.0 μ) were collected for clay differentiation, and the fine sand (0.10 - 0.25 mm) fraction was collected for single grain, mineralogical differentiation.

Clay minerals were differentiated by employing X-ray and differential thermal analyses according to standard procedures as outlined by Twardy (1969). In addition, surface area was determined by evacuation, following treatment with ethylene glycol monoethyl ether (Heilman, Carter and Gonzalez, 1965). Total K_2O content was determined by HCl - HF fusion (Pawluk, 1967).

Components of the fine sand fraction were identified by use of a petrographic microscope, after segregation into three fractions on the basis of specific gravity. A heavy fraction (s.g. >2.96) was obtained by sedimentation in tetrabromoethane and a light fraction (s.g. <2.40) by sedimentation in a 1:3 mixture of benzene and bromoform. The remaining minerals were collected as an intermediate fraction (s.g. 2.40-2.95). These fractions were mounted in aroclor, caedex and castolite, respectively and examined under a petrographic microscope. Grain counts were made on each mount, subdividing the counts per mount to give a total of about 400 counts per horizon.

Experimental Micromorphology

A series of three experiments were conducted in an attempt to reproduce observed microfabrics. Resulting fabrics were analysed using thin section techniques.

Experiment 1

Known weights of pure quartzitic (Ottawa) sand were placed in 50 ml porcelain crucibles. Known weights of calcium saturated,

soil clay were then thoroughly mixed with the sands, after which the material was saturated with distilled water, thoroughly stirred, and then dried at 30°C for at least 24 hours. In total, four clay treatments were tried, clay being added in increments of 10 per cent to yield a range from 10 to 40 per cent clay. Each increment was duplicated; the wetting - drying treatments were repeated ten times with mixing. The clay material used contained approximately 51 per cent montmorillonite, 22 per cent illite, and 27 per cent chlorite, kaolinite and quartz (Twardy, 1969).

Experiment 2

The procedure followed was that outlined for Experiment 1 except that pure quartzitic (Ottawa) sand and natural, soil silt were initially mixed in proportions of 2:1. To this mixture, clay material identical to that used in Experiment 1 was added to give clay percentages of 5, 10, 20, 30, and 40. The material was then mixed, saturated with distilled water, thoroughly stirred and dried at 30°C. The wet - dry treatments were repeated ten times. Each clay treatment was duplicated.

Experiment 3

This experiment was essentially a composite of experiments 1 and 2, except that a 0.5 N $FeCl_2 \cdot 4H_2O$ solution was used in place of distilled water as the saturating medium. In one replicate sufficient clay material was added to give 10 per cent clay in a 2:1 mixture of sand and silt. In the other replicates clay material was added to pure quartzitic (Ottawa) sand to yield samples containing 10 per cent and 20 per cent clay. Each clay treatment was duplicated, and the wet - dry procedures were repeated five times.

RESULTS AND DISCUSSION

Field Studies

Most upland soils have common features which are characteristic to the area. At the surface there is usually a dark gray to dark grayish brown colored Ahk horizon, showing fine granular to weakly expressed single grain structure. Thickness of the Ahk is commonly less than 2 inches at the eastern extremity of the study area, but becomes progressively thicker towards Brulé Lake. In the region immediately east of Brulé Lake the thickness is upwards of 4 to 5 feet.

Beneath the Ahk there is a thick, distinct, yellowish brown to yellowish red colored "paleo" B horizon (see Plate 3) which again appears very near the surface at the eastern extremity of the area, but becomes buried progressively deeper as Brulé Lake is approached. This horizon is generally weakly structured, friable, and porous. Within this horizon, internal clay translocation has in many cases resulted in development of a weakly expressed Ae, Bt horizon sequence, with very slight bleaching in the Ae and slight darkening in the Bt. Such

Plate 3. Loess overlying bedded gravels in a borrow pit. "Paleo" B horizon (reddish brown) is buried at a depth of about 30 inches.

clay reorganization was observed to occur entirely within the "paleo" B horizon where the thickness of the aeolian deposit was greater than 1 foot, but illuvial horizons were also found to encroach into underlying till where thickness was less than 1 foot. In areas where the aeolian deposits overlaid gravels, thereby causing excessive internal drainage or where the "paleo" B horizon was buried to depths greater than about 10 inches, no horizons of clay accumulation were evident.

The significance of the "paleo" B horizon is not entirely understood, but its field distribution is analogous to the buried and relic soil concept of Ruhe (1969). In the western portion of the area this horizon is buried to depths of 7 to 8 feet by dark grayish brown, accreted Ahk material. This latter material is often stratified, and contains high amounts of both organic matter and charcoal fragments. Thin, incipient, pale red B horizons are common within the Ahk material, indicating that burial was sporadic rather than continuous.

A charcoal fragment taken from the middle of the "paleo" B horizon at Pocahontas dated 2730 $\pm$ 100 B.P. (Isotopes, Inc., 1 - 3672). Roed (1969) reported dates of 2190 $\pm$ 170 B.P. (Isotopes, Inc., 1 - 2614) years for a deeply buried charcoal bed, and 1300 $\pm$ 95 B.P. (Isotopes, Inc., 1 - 2613) years for an upper charcoal bed. These latter two dates were both from the overlying Ahk material.

A common feature of all soils in the area is the presence of carbonates throughout the solum. Field investigations and laboratory analysis revealed highest carbonate contents to be in A and C horizons, with contents in B horizons being intermediate and sometimes quite low. The presence of carbonates in surface horizons of well differentiated

soils is contrary to current theories on soil formation, and was interpreted as evidence for the accretionary nature of these soils. Plate 4 shows soils typical of the area.

Major soils recognized in the field were as follows:

<u>Calcareous Regosols</u> - Calcareous Orthic Regosols were differentiated from Calcareous Cumulic Regosols in that the former consisted essentially of aeolian material subject to active erosion (active dunes) while the latter exhibited a horizon of organic matter accumulation but little or no evidence of profile differentiation. These soils occurred only in regions where erosion and deposition of aeolian material were most active. They were commonly underlain by recurring series of buried soils with Ahk, Bmk horizonation.

<u>Calcareous Eutric Brunisols</u> - These soils had thin organic surface horizons (L-Hk), and Ahk horizons which were less than 2 inches thick. These horizons were underlain by brown to yellowish red (7.5YR 4/4 - 5 YR 5/6) subsurface horizons, which were commonly 8 - 12 inches thick. The soils were friable, and structures were weakly expressed. Generally till or cobbly gravel lay directly beneath the soil solum. Calcareous Orthic Eutric Brunisols were differentiated from Calcareous Degraded Eutric Brunisols by the presence of a weakly to moderately well expressed Aek horizon in the latter soil.

<u>Calcareous Moder Melanic Brunisols</u> - Profile horizonation within this soil group was similar to that of Eutric Brunisols except for the thickness of the Ahk which was allowed to vary from 2 to 20 inches. The Ahk was commonly very dark brown to dark reddish brown (10YR 3/2 - 5YR 3/2) in color, friable in consistence, and possessed a characteristic, poorly developed, fine granular structure. It was

Plate 4.1. Calcareous Orthic Moder Melanic Brunisol.

Plate 4.2. Calcareous Degraded Moder Melanic Brunisol.

Plate 4.3. Calcareous Brunisolic Moder Gray Brown Luvisol.

Plate 4.4. Calcareous Brunisolic Gray Luvisol.

underlain by a yellowish red to yellowish brown (5YR 4/6 - 10YR 5/8) Bmk horizon with poorly developed subangular blocky to single grain structure, and friable consistence. Beneath this there was often a brownish yellow (10YR 6/4 -6/8) BCk horizon which in turn was underlain by a light brownish gray (10YR 6/2) Ck horizon. In some cases the solum lay directly on till or cobbly outwash material.

In regions where the Ahk was particularly thick, a series of recurring, weak Ahk, Bmk horizon sequences were present. These horizons, however, were not considered in classification.

Calcareous Orthic Moder Melanic Brunisols were differentiated from Calcareous Degraded Moder Melanic Brunisols on the basis that an incipient Aek was present in the latter soil. On the basis of field morphology, however, it was often impossible to determine whether the bleached appearance evident in the Aek was due to eluviation, or whether this was a subzone of carbonate accumulation.

Calcareous Brunisolic Moder Gray Brown Luvisols - The Calcareous Brunisolic Moder Gray Brown Luvisolic soils were characterized by an L-Hk, Ahk, Bmk, Ae2k, Btk, Ck horizon sequence. Character of the Ahk was very similar to that described for Moder Melanic Brunisols. The variability in thickness and frequent banding common in this horizon testified to the aeolian origin of this material. This horizon was underlain by a yellowish red to reddish yellow (5YR 4/6 - 7.5YR 6/6) Bmk horizon below which was a strong brown to yellowish brown (7.5YR 5/6 - 10YR 5/6) Ae2k horizon. These latter two horizons commonly occupied about 10 - 15 inches of the solum.

The Btk horizon was yellowish brown to brown (10YR 5/4 - 7.5YR 4/4) in color, and possessed weakly expressed prismatic to subangular blocky

structure. It was quite friable in the moist state, but became hard to very hard upon drying. This horizon appeared to be weakly cemented by clay and iron components, but was highly vesicular. Cutanic accumulations were rare. The horizon was commonly 4 to 6 inches thick, and was usually underlain by 4 to 30 inches of grayish brown to olive brown (2.5YR 2/2 - 4/4) Ck material, below which was gravel or till.

Calcareous Brunisolic Gray Luvisols - These soils occur towards the eastern portion of the area where both carbonate content and thickness of aeolian material appear to be relatively lower, and where the "paleo" B horizon appears at the surface. Profile horizonation in this soil is commonly L-Hk, Bmk, Ae2k, Btk, Ck. A thin (less than 2 inches) Ahk horizon is often present, and the solum sometimes rests directly on till material.

The Bmk horizon is commonly dark reddish brown to brown (5YR 3/2- 7.5YR 4/4) in color, poorly structured, and friable in consistence. It is underlain by a yellowish brown to strong brown (10YR 5/4 - 7.5YR 5/4) Ae2k horizon. Beneath this is a dark yellowish brown to strong brown (10YR 4/4 - 7.5YR 5/6) Btk horizon which is weakly structured. Consistence in the Btk is friable in the moist state, but slightly hard when dry. Cementation appears to be slightly weaker than that of the Calcareous Brunisolic Moder Gray Brown Luvisol. Solum thickness varies between 10 and 30 inches.

Soil Associations

A continual, predictable soil distribution pattern occurs within the mapped area. This pattern is illustrated on the general soil map included in the pocket inside the back cover of this thesis, and pertinent portions of the distribution pattern are further outlined

by the topographic cross-sections at the bottom of the map.

A form of horizontal zonality, based on distance from the loess source region, is a common feature of the area, and is illustrated in cross-section A - B. Regosolic soils are found in regions where loess deposition as well as active erosion of aeolian materials is greatest. Calcareous Orthic Regosols occur in areas immediately adjacent to Brulé Lake, but soon give way to Calcareous Cumulic Regosols. Because of local variability in topography, whereby burial of the "paleo" B horizon varies within $\pm$ 20 inches, soil associations in the latter region are a complex between Calcareous Cumulic Regosols and Calcareous Moder Melanic Brunisols.

In adjacent areas, where burial of the "paleo" B horizon is continually less than 20 inches, the soil associations change to a combination of Calcareous Orthic and Calcareous Degraded Moder Melanic Brunisols. This association tends to be catenary in that Calcareous Orthic Moder Melanic Brunisols occupy hillcrests, while Calcareous Degraded Moder Melanic Brunisols tend to occur on the lower positions of side slopes.

Progressing eastward, where presence of a prominent topographic feature elevates the "paleo" B horizon to within 10 - 15 inches of the surface, the soil association becomes a complex between Calcareous Brunisolic Moder Gray Brown Luvisols and Calcareous Orthic Moder Melanic Brunisols. In this area one can also encounter Calcareous Degraded Moder Melanic Brunisols, as well as Calcareous Orthic Moder Gray Brown Luvisols. However, the occupancy of these latter two soils is estimated to be less than 20 per cent of the area and therefore they were not included as part of the map unit. Thin, discontinuous stone lines

can sometimes be encountered in Btk horizons in this area.

The association between Calcareous Brunisolic Moder Gray Brown Luvisols and Calcareous Orthic Moder Melanic Brunisols is not readily understood and therefore difficult to explain. However, field observations indicate that burial of the "paleo" B horizon at depths of 10 - 15 inches is insufficient to preclude further pedological differentiation. Such soils, therefore, remain within the zone of active pedogenesis whereby clay translocation within the "paleo" B horizon results in the formation of an Ae, Bt horizon sequence. Where burial is greater, no evidence of horizon differentiation within the "paleo" B is evident. In eastern portions of this region, where local relief is particularly great, erosion of the overlying Ahk becomes a factor, and soil associations change to a complex of Calcareous Brunisolic Gray Luvisol and Calcareous Brunisolic Moder Gray Brown Luvisol.

It has been previously stated that the thickness of the Ahk horizon progressively decreases in a leeward direction from Brulé Lake. Because of the concave nature of the Athabasca River valley, this decrease pinches out to insignificance in the vicinity of the Hinton pulp mill. Correspondingly, soil associations immediately west of the mill are complexes of Calcareous Moder Melanic Brunisols, while those to the east are complexes of Calcareous Eutric Brunisols. Both soil groups are usually directly underlain by gravels of the Hinton terraces. It may be for this reason that internal clay translocation is not evident within the "paleo" B horizon.

Along with horizontal soil zonality, there is also a predictable pattern of vertical soil distribution. This aspect is indicated on

topographic cross-sections C-D and E-F, as well as on the general soil map.

The exact nature of the vertical zonality is related directly to horizontal distribution. In western portions of the study area, where aeolian material is in ample supply, the lowest elevations of the valley are occupied by Calcareous Moder Melanic Brunisols. These soils extend to about 3,600 feet a.s.l. above which the associations change to a complex of Calcareous Moder Melanic Brunisols and Calcareous Brunisolic Moder Gray Brown Luvisols. This association may extend to the boundary of the calcareous area in regions where deposition is relatively active, or it may yield to Calcareous Brunisolic Gray Luvisols where deposition of aeolian material is only occasional. In cross-section C-D this transition occurs at about 4,000 feet a.s.l.

In the eastern portion of the area, where the aeolian deposit is thinner and presence of the Ahk horizon becomes insignificant, the lowest portions of the valley are occupied by Calcareous Eutric Brunisols. These soils extend to approximately 3,300 feet a.s.l., above which Calcareous Brunisolic Gray Luvisols are found. The limit of the calcareous area in this region is about 3,600 feet a.s.l.

The presence of calcareous aeolian material has an influence on soil development in regions far beyond the extent of the calcareous area as outlined in the enclosed soil map. As mentioned previously, aeolian material has been traced as far east as Galloway, and field observations indicate a progressive increase in depth to lime as one progresses eastward. This illustrates a progressive decrease in the amount of lime supplied to the surface of the soil, thereby allowing eluviation to remove it to ever greater depths. In accord with the

depth to lime function, there is a corresponding zonation in soil reaction which grades from 8.0 - 8.5 in the Hinton area to 6.0 - 6.5 in the region of Galloway.

There is a corresponding distribution of soil profile types in conformity with the regional zonation in pH and depth to lime. Soils with Brunisolic Gray Luvisol morphology, but alkaline reaction, occur as a "halo" around the calcareous region irrespective of material or topography. However, as quantity of both lime and aeolian material decreases, the prevalence of Brunisolic Gray Wooded soil decreases and the incidence of Orthic Gray Wooded soil increases. Correspondingly, the regional pH of the solum decreases to below neutrality. Soil regions entirely beyond the influence of calcareous, aeolian material are characterized by the presence of Orthic Gray Luvisols and Bisequa Gray Luvisols, and their sola are moderately to strongly acid.

Miscellaneous Land Units

Poorly Drained Land

Such land has impeded internal drainage and, therefore, is one in which gleysolic processes predominate. It is located in topographically low positions, beneath black spruce, larch, and other hydrophyllic vegetation. Soils include Orthic and Rego Gleysols with less than 16 inches of surface peat, and Typic Humisols or Terric Mesic Humisols where peat accumulation exceeds 16 inches.

Eroded Stream Channels

These are highly dissected land units with steep topography, usually bordering rivers and streams. Soils are highly subject to erosion and therefore immature.

Alluvium

These are undifferentiated, recent, river deposited materials, of variable texture and composition. Soils are generally Orthic and Cumulic Regosols.

Disturbed Land

This includes soils which have been extensively disturbed by the activities of man. Such areas are located only in the region of Hinton town sites.

Open Water

These are areas in which water remains on the surface of the land throughout the summer.

Soil Characterization and Classification

Representative soils were sampled in replicate for purposes of soil characterization and classification. Analytical procedures used were identical to those employed by the Soil Survey laboratories of the Alberta Institute of Pedology. Results are summarized in Table 1; individual profile descriptions are contained in the Appendix.

Perusal of the data indicates that the Eutric Brunisols are similar in morphology and chemical characteristics (except pH) to ones reported previously (Pawluk and Lindsay, 1964). Although analytical results are cited for Ahk horizons, these horizons are usually less than two inches thick. Melanic Brunisols and Gray Brown Luvisols, on the other hand, show similar morphology but slightly lower iron contents and higher pH values than morphologically similar soils of Ontario (Gillespie and Richards, 1957; Gillespie, Wicklund and Matthews, 1966; Hoffman, Miller and Wicklund, 1967).

Particle size analyses indicate the possibility of the presence

Table 1. Analytical Characteristics of the Soils

Chemical Analyses

Hor.	pH	%N[1.]	%O.C.[2.]	$\%CaCO_3$ Equiv.	Oxalate %Fe	Oxalate %Al	Dithionite %Fe	Dithionite %Al
				Calcareous Orthic Eutric Brunisol (Means of two sites).				
Ahk	7.5	0.63	18.71	2.92	0.36	0.08	0.83	0.08
Bmk	7.7	0.12	2.30	0.82	0.66	0.19	1.09	0.10
llCk	Unsampled material. Generally outwash gravels or Obed till.							
				Calcareous Degraded Eutric Brunisol (Means of four sites).				
Ahk	7.5	0.61	13.62	3.88	0.57	0.15	0.99	0.11
Aek	7.8	0.10	1.76	1.84	0.45	0.12	0.77	0.06
Bmk	7.8	0.04	0.64	0.61	0.26	0.13	0.96	0.08
llCk	Unsampled material. Generally outwash gravels or Obed till.							
				Calcareous Orthic Moder Melanic Brunisol (Means of four sites).				
Ahk	8.1	0.22	3.91	21.85	0.62	0.14	0.81	0.06
Bmk	8.2	0.05	0.51	2.20	0.36	0.15	0.71	0.06
BCk	8.0	-	-	1.50	0.20	0.06	0.78	0.07
Ck	8.1	-	-	11.40	0.24	0.07	0.48	0.04
				Calcareous Degraded Moder Melanic Brunisol (Means of four sites).				
Ahk	7.9	0.32	5.32	15.12	0.62	0.11	0.89	0.08
Aek	8.0	0.09	1.20	4.27	0.42	0.16	0.77	0.05
Bmk	7.9	0.02	0.24	0.58	0.20	0.07	0.74	0.03
BCk	7.9	-	-	0.44	0.23	0.18	0.52	0.03
Ck	8.0	-	-	13.78	0.10	0.06	0.36	0.04

1. Total Nitrogen
2. Organic Carbon

Table 1. Analytical Characteristics of the Soils

Particle Size Analyses

Hor.	% V.C.S.[3]	% C.S.[4]	% M.S.[5]	% F.S.[6]	% V.F.S.[7]	% Total Sand	% Silt	% Total Clay[8]	% Fine Clay[9]
Calcareous Orthic Eutric Brunisol (Means of two sites).									
Ahk	0.4	1.7	0.7	1.5	5.4	9.5	79.0	11.5	5.5
Bmk	2.6	5.2	2.5	4.8	8.4	23.0	63.0	14.0	5.0
11Ck	Unsampled material. Generally outwash gravels or Obed till.								
Calcareous Degraded Eutric Brunisol (Means of four sites).									
Ahk	1.0	1.6	1.7	3.7	7.9	16.0	66.0	18.0	6.3
Aek	1.2	2.6	2.9	8.6	10.6	26.2	60.5	13.2	5.8
Bmk	1.9	4.5	5.2	13.2	14.7	39.8	46.2	14.0	8.0
11Ck	Unsampled material. Generally outwash gravels or Obed till.								
Calcareous Orthic Moder Melanic Brunisol (Means of four sites).									
Ahk	0.1	1.8	2.9	8.3	17.1	30.5	56.2	13.5	4.2
Bmk	1.2	6.8	8.9	23.5	19.8	60.8	31.8	7.5	4.0
BCk	-	1.6	0.8	34.5	28.2	65.5	25.0	9.5	6.5
Ck	1.8	4.2	7.3	34.9	28.5	76.0	19.0	5.7	3.0
Calcareous Degraded Moder Melanic Brunisol (Means of four sites).									
Ahk	0.1	1.0	1.8	8.5	19.6	30.8	59.2	10.0	3.0
Aek	0.4	2.8	5.4	27.0	17.6	53.5	38.8	7.5	4.0
Bmk	0.2	2.9	7.1	36.0	24.8	71.2	21.2	7.2	4.0
BCk	0.2	3.7	8.7	45.5	21.4	79.0	15.0	6.0	4.0
Ck	0.6	7.0	12.7	30.2	27.4	78.5	15.0	6.5	3.5

3. Very Coarse Sand
4. Coarse Sand
5. Medium Sand
6. Fine Sand
7. Very Fine Sand
8. $< 2.0\ \mu$
9. $< 0.2\ \mu$

Table 1. Analytical Characteristics of the Soils (Cont.)

Chemical Analyses

Hor.	pH	%N	%O.C.	$\%CaCO_3$ Equiv.	Oxalate %Fe	Oxalate %Al	Dithionite %Fe	Dithionite %Al
Calcareous Brunisolic Moder Gray Brown Luvisol (Means of four sites).								
Ahk	7.8	0.28	4.43	18.08	0.62	0.16	0.82	0.10
Bmk	8.0	0.03	0.21	1.33	0.19	0.09	0.65	0.02
Aek	8.0	0.02	0.12	0.71	0.15	0.05	0.83	0.02
Btk	7.8	0.04	0.26	0.90	0.24	0.10	0.96	0.03
Ck	8.0	-	-	13.79	0.22	0.06	0.76	0.02
Calcareous Brunisolic Gray Luvisol (Means of four sites).								
Bmk	7.9	0.12	1.71	1.68	0.56	0.17	0.96	0.08
Aek	7.9	0.03	0.26	0.51	0.16	0.06	0.68	0.06
Btk	7.8	0.04	0.29	0.54	0.22	0.07	0.94	0.08
Ck	8.1	-	-	14.33	0.13	0.03	0.45	0.04

Table 1. Analytical Characteristics of the Soils (Cont.)

Particle Size Analyses

Hor.	% V.C.S.	% C.S.	% M.S.	% F.S.	% V.F.S.	% Total Sand	% Silt	% Total Clay	% Fine Clay
Calcareous Brunisolic Moder Gray Brown Luvisol (Means of four sites).									
Ahk	0.1	0.3	0.5	6.5	20.1	23.9	65.2	10.8	4.2
Bmk	-	0.2	1.6	23.9	41.9	58.2	34.8	7.2	3.5
Aek	0.1	0.2	0.6	18.3	46.7	62.2	30.2	7.8	3.2
Btk	-	0.1	0.2	10.7	38.2	54.2	30.5	15.0	8.5
Ck	0.2	0.3	0.5	12.1	41.2	52.2	39.8	8.0	4.5
Calcareous Brunisolic Gray Luvisol (Means of four sites).									
Bmk	0.2	1.4	3.5	13.4	17.4	36.2	51.8	12.0	4.8
Aek	0.1	1.6	5.8	24.8	26.8	59.2	33.0	7.8	3.0
Btk	0.2	2.3	7.0	27.2	25.8	62.5	26.2	11.2	7.0
Ck	0.1	1.0	4.8	25.6	35.7	67.0	28.0	5.0	4.0

of two types of aeolian material, in that surface, humified horizons contain considerably more silt and less sand-sized materials than do horizons situated within the "paleo" B. This suggests the possibility of a hiatus in deposition. Internal clay translocation within the confines of the "paleo" B horizon is indicated by the presence of Ae2k and Btk horizons in eastern portions of the area. The amount of clay translocation, however, is often minimal in terms of an argillic horizon (Soil Survey Staff, 1960).

The uniqueness of the soils studied is indicated by the following two properties:

1. The sola of all soils show varying degrees of effervescence upon treatment with dilute HCl. Correspondingly, reaction throughout the solum is mildly to moderately alkaline. In spite of this, the soils show distinct horizonation associated with the translocation of both iron and clays. Cutanic accumulations, however, are not discernible.
2. The soils possess well developed Ahk horizons regardless of the fact that soils in surrounding areas are of the Gray Wooded type. Micromorphological studies (to be discussed later) indicate the humus form of these horizons to be moder or mull-like moder.

Soils of such unconforming character are not easily included in any of the common soil classification schemes. In fact, extensive scanning of the available literature produced only one reference (Kubiena, 1953) in which soils of approximately analogous character are described. These are Calc-Braunerde soils which occur on steep

landforms where washings from upper slope marl or chalk deposits add a continual supply of lime to the surface of the profiles. Such soils differ from those in the Hinton area in that they exhibit a mull humus form in the A horizon.

The unique properties of the soils studied necessitated the creation of new classification categories. They were thus inserted into the Canadian soil classification scheme (N.S.S.C., 1968) via modification of existing Subgroups by the words "Calcareous" and "Moder" where appropriate. Approximate corresponding terms in the American soil classification scheme are suggested as follows (Soil Survey Staff, 1967):

Classification according to the Canadian Soil Classification Scheme	Classification according to the U.S.D.A. "7th Approximation"
Calcareous Orthic Regosol	Cumulic Cryorthent
Calcareous Cumulic Regosol	Cumulic Cryorthent
Calcareous Orthic Eutric Brunisol	Cumulic Cryochrept
Calcareous Degraded Eutric Brunisol	Cumulic Albic Cryochrept
Calcareous Orthic Moder Melanic Brunisol	Cumulic Mollic Cryochrept
Calcareous Degraded Moder Melanic Brunisol	Cumulic Albollic Cryochrept
Calcareous Brunisolic Moder Gray Brown Luvisol	Cumulic Mollochreptic Cryoboralf and Cumulic Glossic Mollochreptic Cryoboralf
Calcareous Brunisolic Gray Luvisol	Cumulic Ochreptic Cryoboralf

Micromorphological Analyses

Descriptive Micromorphology

Thin sections obtained from selected monoliths were described employing established terms and criteria. The thin sections, prepared in duplicate from each 2 - 3 inch depth of the profiles, were selected

to yield a continuous picture of fabric change with depth.

Individual fabrics encountered in the soils under study are described below. Fabric names are modifications of those proposed by Kubiena (1938), Kubiena (1953) and by Barratt(1964). They are followed, in brackets, by names used by Brewer (1964b). Plate 5 shows fabrics typical to those observed in this study.

a. Calcareous Rendzina Moder Fabric and Calcareous Mull-like Rendzina Moder Fabric (Calcareous Intertextic)

This fabric has a "salt and pepper" appearance due to large numbers of charred, organic fragments, as well as considerable quantities of calcium humates. It is completely interspersed with colorless, skeletal grains. Structural development in the macromorphological sense is non-existent, since the binding effects of soil colloids are at best only weakly expressed.

Organic matter content is very high and its distribution throughout the fabric is random. It consists of irregularly shaped, partially decomposed root fragments, rounded to sub-rounded charred fragments (40 - 80 μ), as well as finely comminuted bits (1 - 2 μ) that completely infuse the plasma. Brown humic materials, probably combined with iron, may also be present. Many partially decomposed organic fragments exhibit jagged edges as if they had been attacked by soil fauna (Plate 6). Fungal mycelia are very common. These have also been reported in surface horizons of Brown Podzolic soils of Italy (Valenti and Sanesi, 1967).

Quartz and primary carbonates are the dominant components of the skeletal fraction but considerable quantities of rock fragments and volcanic fragments are also found. Mica and feldspar content is low.

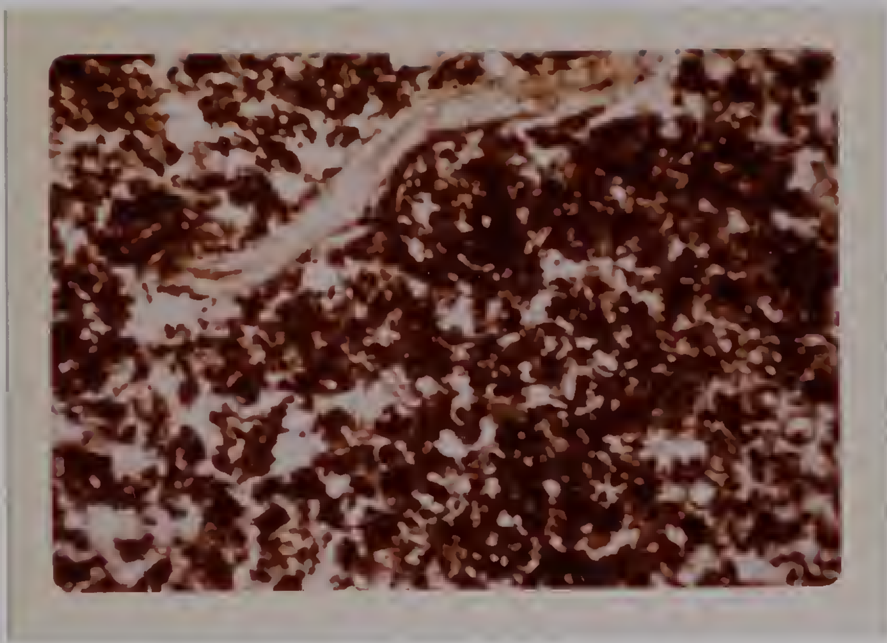

Plate 5.1. Photomicrograph of Calcareous Mull-like Rendzina Moder fabric. Root fragment upper center. Mag. 50X.

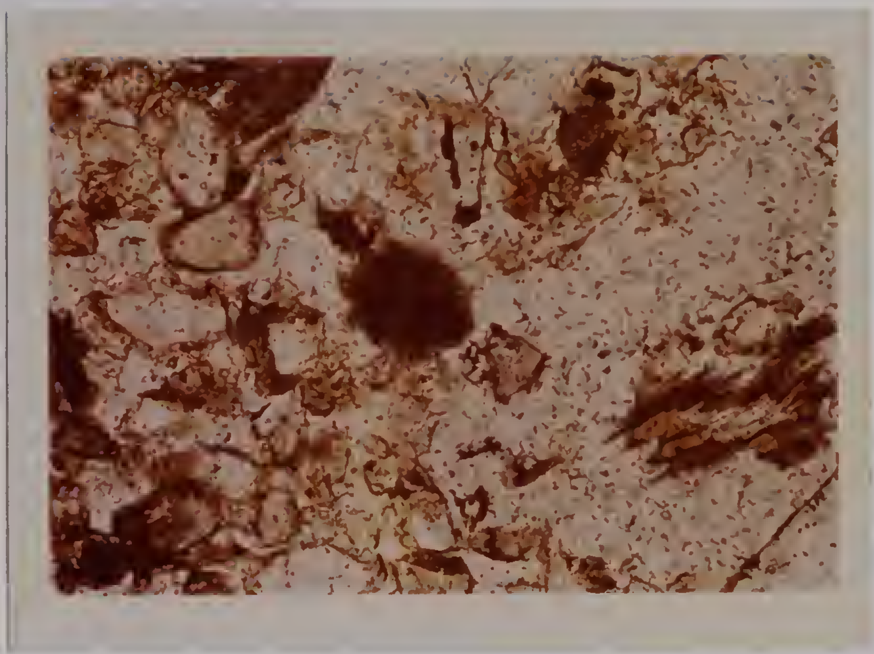

Plate 5.2. Photomicrograph of Calcareous Chlamydomorphic Agglomeratic fabric. Root fragment lower right. Magnification 200X.

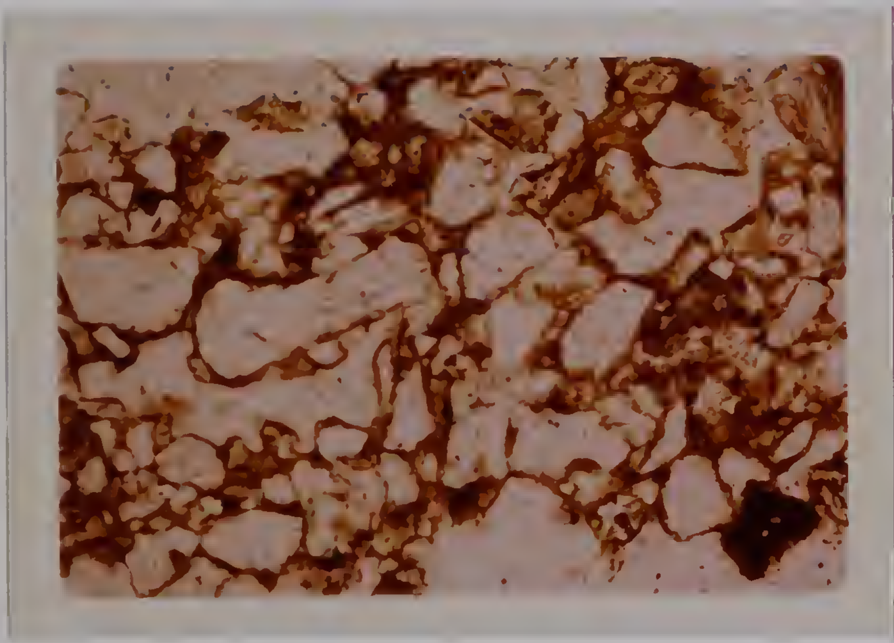

Plate 5.3. Photomicrograph of Calcareous Chlamydomorphic fabric. Magnification 200X.

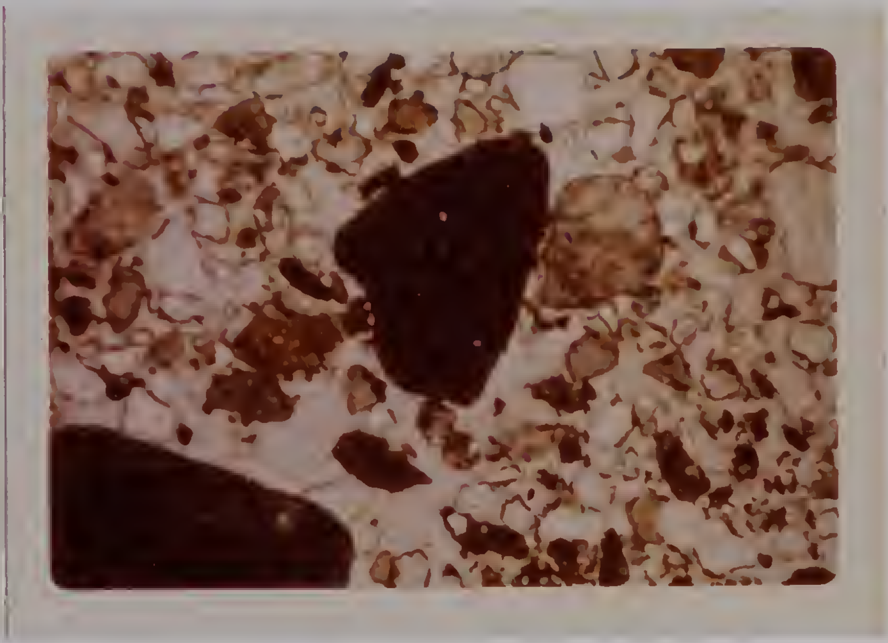

Plate 5.4. Photomicrograph of Calcareous Chlamydomorphic Rendzina fabric. Weathered siderite grain (dark) in the center. Magnification 50X.

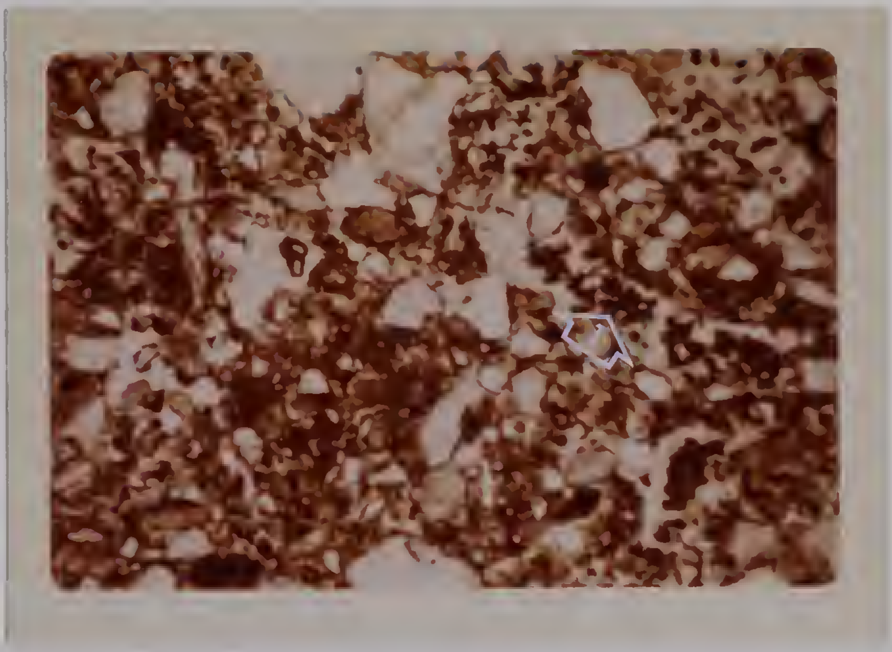

Plate 6. Photomicrograph of an Ah2k horizon showing the result of soil faunal attack on organic matter (1). Magnification 50X.

Size distribution tends to be bimodal (30 - 80 μ vs 100 - 300 μ) but may vary from about 10 μ to 600 μ. The larger size fraction is subangular to subrounded, while the smaller size fraction is angular to subangular. Quartz is of volcanic and metamorphic origin, while rock fragments are of volcanic, metamorphic, and sedimentary origin. Siderite, although rare, can occasionally be observed.

Plasma is yellowish brown to brownish gray in color, and made up of varying proportions of clays, humic materials, and powdery, cryptocrystalline, secondary carbonate precipitates. Most of it is uniformly interspersed with finely comminuted bits of organic matter. It is commonly aggregated into sub-rounded, porous aggregates 50 - 80 μ in diameter which, in some cases, have been weakly cemented by secondary carbonates. In rare instances irregularly shaped, free grain cutans, about 5 μ thick, are present. Associations between colloidal mineral and colloidal organic matter appear to be very weak, resulting in the formation of a porous and friable soil complex.

Characteristic to this fabric is a moderate to high incidence of secondary carbonate precipitates. These may either completely infuse the fabric, or may be concentrated into local, irregularly-shaped, powdery deposits. At the terminus of old root channels, it is common to find macrocrystalline (40 - 60 μ) calcite of secondary origin. In spite of the presence of secondary carbonates, fabric cementation and plasmic-skeletal associations are very weak. Kubiena (1938) believes that the presence of weak bonds in highly calcareous soils makes such soils particularly susceptible to wind and water erosion. These fabrics were found in all Ahk and Ahek horizons of the soils studied.

b. Calcareous Chlamydomorphic Agglomeratic Fabric (Calcareous Skelsepic Agglomeroplasmic)

This is a loose and porous soil fabric in which significant portions of the plasma occur as both incomplete fillings in the interskeletal spaces and as coatings on skeletal grains. It is transitional to both Chlamydomorphic and Agglomeratic fabric. Fabric color is non-uniform brownish gray. Weak and incomplete bonding between plasmic and skeletal material results in the formation of macro-aggregates only sporadically; in most cases this cannot be observed at all. Interskeletal porosity is high while organic matter content is low. The latter commonly takes the form of partially decomposed root fragments, sub-rounded charred fragments, and comminuted bits dispersed throughout the plasma.

Skeletal content in these fabrics is very high and is dominated by quartz. Considerable amounts of rock fragments are also present but contents of primary carbonate, feldspar, and mica are low. Size distribution and grain shapes are similar to those described for

Calcareous Rendzina Moder fabrics.

Fabric plasma is yellowish brown to brownish gray in color and appears to be made up predominantly of clays and humic material. It is also uniformly interspersed by comminuted bits of organic matter. Much of the plasma is organized into weak, loosely-adhering free grain cutans which are commonly 5 - 8 μ thick. Considerable portions are also coagulated or granulated into equidimensional, loose granules (about 100 μ in diameter) which occur as interskeletal fillings or form interskeletal braces. Both types of plasmic structures appear to be rather loose and crumbly, and therefore would be highly susceptible to wind or water erosion. Contrary to Calcareous Rendzina Moder fabrics whereby secondary carbonates often seem to infuse major portions of the matrix, carbonates in these fabrics seem to be concentrated in discrete portions of the fabric, and are of the cryptocrystalline type. Such areas are commonly adjacent to former root channels, but are not restricted to these regions. This indicates that soil solutions may move as a front through surface horizons, but tend to follow discrete channels in sub-surface horizons. Major portions of the fabric appear to be relatively free of secondary carbonate precipitates, but where these are present they are capable of weakly cementing portions of the fabric.

At irregular locations in the fabric there are discrete areas in which materials high in iron and perhaps in organic matter are concentrated. These take the form of either well expressed free grain cutans, or free grain cutans associated with well defined interskeletal braces in regions where the content of plasma is sufficient. In these latter areas the iron seems to be differentiated into brownish red

aggregates surrounded by pale yellow borders. The former may be goethite while the later may be a form of limonite. The form and size (300 - 1,000 μ) of these areas suggests that they be called glaebules (Brewer, 1964b).

Calcareous Chlamydomorphic Agglomeratic fabric proved to be the most common fabric type in the soils studied. It was present in all Bmk, BCk, and Aek horizons, as well as in the lower section of some Ahk horizons.

c. Calcareous Chlamydomorphic Fabric (Calcareous Skelsepic Granular)

In this fabric every mineral grain is surrounded by a uniform colloidal coating. Overall fabric color varies from deep brown to brownish gray, interspersed with colorless mineral grains. Organic matter content is low, and interskeletal porosity is high. Macrostructural aggregation is weak and sporadic because of the generally low plasmic content. Bonding between plasmic and skeletal constituents, however, is considerably stronger than in Chlamydomorphic Agglomeratic fabric.

Skeletal content in this fabric is very high and is dominated by quartz. Considerable amounts of rock fragments are also present but the content of feldspars, micas, and volcanic fragments is low. Size distribution, grain shape, and origin of the skeletal fraction is similar to that described for Calcareous Rendzina Moder fabrics.

Plasma color varies from brown to reddish brown, and appears to be made up predominantly of clays and associated iron humates. The greatest portion of the plasma is highly organized, and most of it exists as free grain cutans surrounding skeletal grains. In most cases there is no evidence of infusion of secondary carbonates into the cutans,

although carbonate precipitates are located sporadically throughout the fabric. Thickness of the free grain cutans varies from about 10 - 15 μ.

Although plasmic distribution throughout the fabric is quite uniform, there can often be observed local areas which exhibit greater plasmic concentrations than do surrounding regions. Within these latter areas free grain cutans are considerably thicker (30 - 50 μ), sometimes being of sufficient thickness to initiate formation of incipient, interskeletal braces. Such cutans can be predominantly clay material, iron material, organic matter or various combinations thereof. In the case of iron material, one can often observe very fine laminations (about 0.2 μ thick) oriented parallel to skeletal grain surfaces (Plate 7). In addition there is often a segregation of color in that brownish red areas occurring in interskeletal spaces are surrounded by yellowish red films. Extinction patterns show only a fine line which moves diagonally across the feature as the stage is rotated. Such color segregation could either be due to authigenic differentiation into geothite and limonite, or it could merely be reflections of varying iron content.

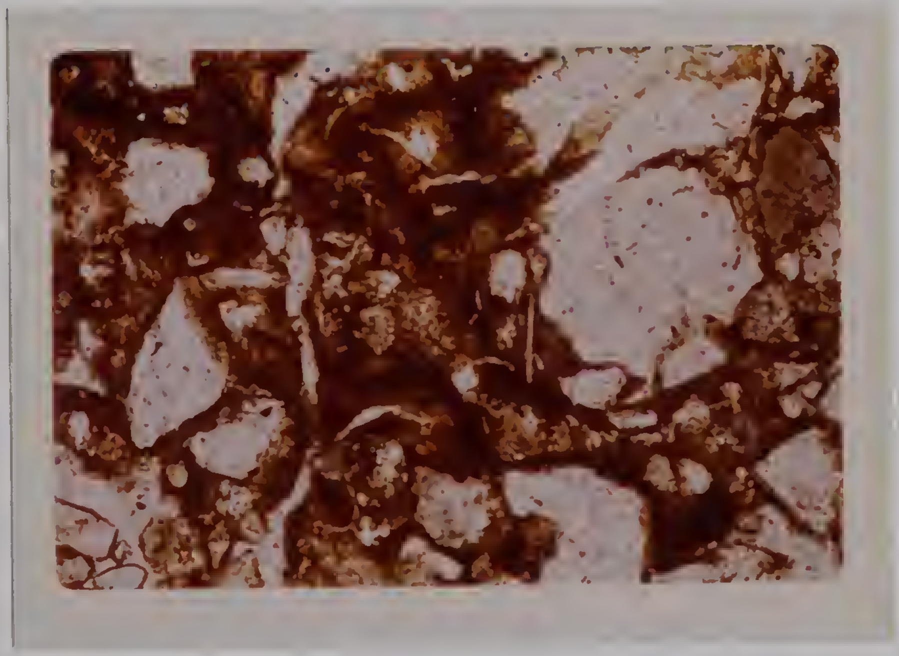

Plate 7. Photomicrograph of Chlamydomorphic fabric with iron-organic matter (?) flow structures (organo-ferrans). These appear as reddish-brown to black concentrations around skeleton grains. Magnification 200X.

In any case, areas high in iron are morphologically similar to ferrans and glaebules, while those high in clay are similar to argillans and papules. In most cases such structures are interpreted as representing illuviation.

In sandy soil material, Chlamydomorphic fabric represents the highest possible state of plasmic organization. Within the soils studied the occurrence of this fabric was restricted exclusively to Btk horizons.

d. Calcareous Chlamydomorphic Rendzina Fabric (Calcareous Skelsepic Agglomeroplasmic)

This fabric contains brown to yellowish brown plasma, pale brownish gray carbonates, and clear, colorless mineral grains. The resultant overall fabric color is a subdued, splotchy, brownish gray. The fabric is very loose and friable due to an overabundance of skeletal grains, and a general lack of plasma. Bonding between skeletal grains and plasmic substances is extremely weak, and macromorphological structural formations are absent. Organic matter exists as root fragments as well as sub-rounded, charred fragments, but its overall content is very low.

This fabric is dominated by skeletal materials. Quartz is the most common constituent, but the content of primary carbonates and rock fragments is also very high. Feldspar and mica contents are very low. Siderite can be located in rare cases. Size distribution, grain shapes, and provenance are similar to those described for Calcareous Rendzina Moder fabrics.

Plasma is brown to yellowish brown in color and appears to predominate in clay material. Some of it is organized into free grain cutans (5 - 8 μ thick); other portions are granulated or coagulated

into microaggregates that loosely occupy interskeletal spaces.

The over-riding feature of the plasma is the high content of secondary carbonate precipitates. These may take the form of cryptocrystalline deposits in which case they tend to completely infuse the plasma or coat skeletal grains (calcans), or macro crystals concentrated in old root channels (Plate 8). Although carbonate content is high, actual cementation of the fabric is relatively rare. In place of cementation, however, infusion of the plasma by secondary carbonate precipitates tends to produce a type of loose, crumbly plasmic aggregation. Such aggregates appear to be highly unstable and their constituents would be easily subject to eluviation given proper conditions.

Calcareous Chlamydomorphic Rendzina fabric is similar to Agglomeratic fabric except for the high incidence of primary carbonates. The author, however, considers the presence of highly soluble constituents, such as primary carbonates, to be of sufficient genetic importance to warrant separation. It also differs from Kubiena's (1938) Rendzina fabric in that organic matter content is very low.

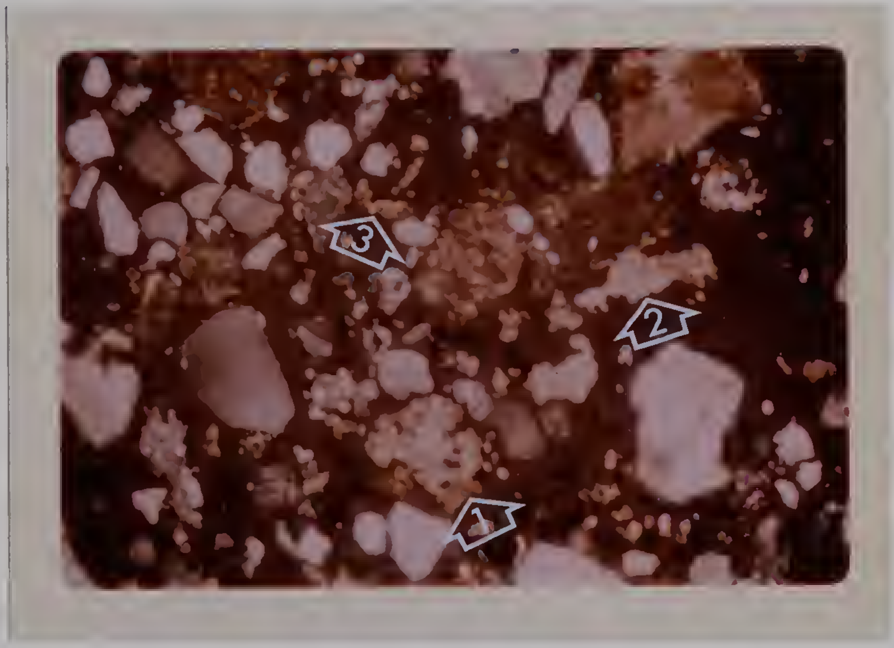

Plate 8. Photomicrograph of Calcareous Chlamydomorphic Rendzina fabric showing primary carbonates (1), macrocrystalline secondary carbonates in a root channel (2), and cryptocrystalline secondary carbonates (3). Partially crossed nicols. Magnification 10X.

However, Kubiena based his description on surface horizons, whereas in these soils this fabric is restricted exclusively to Ck horizons.

Modal Analysis

A modal analysis technique was used to quantitatively evaluate the distribution of micromorphological constituents. Four hundred points per thin section, on each of the duplicate thin sections, were counted. Means of constituents were then tabulated for individual thin sections as well as for duplicate thin sections; the latter group yielded information on the quantitative distribution of constituents with depth. Standard deviations were calculated for groups having an incidence of greater than 2.5 per cent. Results for individual thin sections are contained in the Appendix while means for duplicate sections are shown in Tables 2, 3, and 4.

Surface, humified horizons of all soils contain about 15 - 25 per cent quartz plus feldspar, 3 - 12 per cent primary carbonates, and 2 - 10 per cent rock fragments. Total plasma constitutes about 20 - 30 per cent of these horizons. Most of the plasma exists in a loosely aggregated, unorganized form except for the bottom portions of these horizons where some organization in the form of free grain cutans takes place. Secondary carbonate content varies up to 8 per cent while glaebules and nodular iron makes up 0.1 to 5 per cent. Fragmental organic matter may be as high as 30 per cent and decreases gradually with depth. Total pore space varies from 20 - 40 per cent with a predominance of ortho pores.

Beneath the surface horizons there exists a "paleo" B horizon which in the case of Calcareous Brunisolic Moder Gray Brown Luvisols and Calcareous Brunisolic Gray Luvisols, has been internally

Table 2. Means and standard deviations of micromorphological constituents (grouped according to depth) in Calcareous Orthic and Calcareous Degraded Moder Melanic Brunisols.

Calcareous Orthic Moder Melanic Brunisol

Horizon	Depth (in)	Qtz + Feldspar	Skeleton Prim. Carbonate	Skeleton Rock Frag.	Others
Ah1k	0-2.5	19.2±6.6*	10.8±4.4	7.0±3.8	0.6
Ah2k	2.5-5	30.4±7.2	4.6±4.1	11.6±5.8	0.5
Bmk	5-7.5	31.6±6.3	0.9	15.0±8.6	0.8
	7.5-10	31.1±3.9	2.4	19.1±5.3	0.4
Ck	10-13	30.0±6.6	12.8±4.6	18.5±4.6	0.4

Calcareous Degraded Moder Melanic Brunisol

Horizon	Depth (in)	Qtz + Feldspar	Skeleton Prim. Carbonate	Skeleton Rock Frag.	Others
Ahk	0-3.5	15.5±6.6	3.0±2.3	1.8	0.8
Aek	3.5-8	28.0±7.1	3.2±2.7	5.1±2.4	0.9
Bm1k	8-11.5	34.4±5.5	0.5	11.4±5.1	1.1
Bm2k	11.5-15.5	36.8±5.2	0.2	9.5±3.1	1.1
BC1k	15.5-19	36.9±5.1	0.1	9.0±3.7	0.9
BC2k	19-23	37.5±5.1	0.8	13.9±6.1	1.2
Ck	23-27	37.8±5.4	9.0±4.7	11.8±6.0	0.8

* Standard deviations are traverse deviations based on 16 traverses. An approximation of the standard deviation of the grand total mean may be obtained by use of the formula $s_{\bar{x}} = \frac{s_t}{\sqrt{n_t}}$ where s_t is the traverse standard deviation and n_t is the number of traverses. All values are per cent.

Table 2. Means and standard deviations of micromorphological constituents (grouped according to depth) in Calcareous Orthic and Calcareous Degraded Moder Melanic Brunisols.

	Plasma		Pores			
Glaebules	F.G.C.*	Second. Carbonates	Other	Ortho	Meta	Organic Frag.
Calcareous Orthic Moder Melanic Brunisol						
1.0	0.6	3.6±2.9	16.2±5.6	21.0±4.9	0.2	19.0±4.7
1.8	4.9±2.1	3.1±2.3	19.8±5.9	15.5±4.2	1.4	6.4±3.6
1.1	12.0±3.1	0.8	13.4±2.8	15.4±4.3	7.2±3.9	1.9
0.2	11.2±4.2	2.1	10.1±3.4	13.0±4.7	6.6±3.0	3.6±2.3
0.1	3.0±2.1	1.8	7.8±2.4	22.2±4.9	0.0	1.8
Calcareous Degraded Moder Melanic Brunisol						
0.1	0.1	3.8±2.8	17.8±4.9	33.1±5.1	0.0	24.1±7.5
1.0	2.4	6.0±2.8	23.1±7.1	19.5±5.4	1.0	9.8±4.2
0.0	17.1±3.6	1.6	13.5±4.2	13.9±4.6	5.6±3.9	0.9
0.2	17.9±3.5	1.2	11.9±4.3	13.2±4.1	5.5±2.9	2.0
0.6	12.2±4.2	1.2	17.1±3.6	17.9±6.5	2.5±2.6	1.9
0.2	8.9±2.4	1.1	15.6±4.1	19.8±5.4	0.4	0.6
0.0	1.6	4.5±4.0	11.5±3.8	20.9±5.2	0.0	1.5

* Free grain cutans.

Table 3. Means and standard deviations of micromorphological constituents (grouped according to depth) in a Calcareous Brunisolic Moder Gray Brown Luvisol.

Calcareous Brunisolic Moder Gray Brown Luvisol

Horizon	Depth (in)	Skeleton Qtz + Feldspar	Prim. Carbonate	Rock Frag.	Others
Ahk	0-3	20.8±5.3	12.6±5.0	1.6	0.6
	3-6	24.1±4.7	11.4±3.8	2.1	0.6
Ahek	6-8.5	20.0±5.8	11.4±6.0	3.1±2.4	0.5
	8.5-11	20.9±6.0	9.1±3.8	2.8±2.3	0.5
Bmk	11-14	40.4±7.4	2.0	3.9±3.0	0.9
	14-16.5	45.4±5.9	1.2	4.5±2.5	0.8
Aek	16.5-19	47.5±5.3	0.9	4.6±2.7	1.4
	19-21	47.2±5.7	0.8	4.6±3.1	1.4
Btk	21-24.5	34.2±5.8	0.8	2.0	1.0
	24.5-28	37.6±5.9	0.9	4.0±2.2	1.6
Ck	28-32	37.6±4.6	11.0±3.9	4.1±2.6	1.5

Table 3. Means and standard deviations of micromorphological constituents (grouped according to depth) in a Calcareous Brunisolic Moder Gray Brown Luvisol.

Calcareous Brunisolic Moder Gray Brown Luvisol

	Plasma			Pores		
Glaebules	F.G.C.	Second. Carbonates	Other	Ortho	Meta	Organic Frag.
1.5	1.1	0.0	18.2±5.2	26.0±9.2	0.0	16.2±6.6
2.9±2.1	1.7	0.4	22.9±7.6	19.4±4.8	0.0	13.5±3.6
2.8±2.4	3.2±2.1	2.2	22.1±5.7	22.0±4.7	0.9	10.6±2.7
1.7	3.4±1.9	2.0	23.8±4.5	24.1±5.2	1.2	10.1±5.8
1.1	9.4±2.8	1.8	9.8±5.6	23.9±4.8	3.9±2.5	2.9±2.8
0.8	10.2±3.1	2.1	8.4±2.3	21.4±5.1	3.1±2.4	2.1
0.5	6.1±2.0	1.5	10.6±2.6	22.5±4.5	2.2	2.1
0.8	6.5±2.3	1.9	10.4±2.8	24.6±5.3	1.2	0.6
1.0	22.4±3.9	0.9	9.5±3.2	15.4±5.4	11.2±4.6	1.6
0.8	20.8±3.7	0.5	9.6±2.8	12.8±4.3	10.0±3.3	1.5
1.6	2.8±1.8	6.4±2.7	10.1±3.0	21.1±4.8	0.6	2.8±1.9

Table 4. Means and standard deviations of micromorphological constituents (grouped according to depth) in a Calcareous Brunisolic Gray Luvisol.

Calcareous Brunisolic Gray Luvisol

Horizon	Depth (in)	Qtz + Feldspar	Skeleton Prim. Carbonate	Rock Frag.	Others
Bm1k	0-3	38.1±6.8	1.0	5.6±2.8	1.2
Bm2k	3-5	37.1±5.3	0.1	6.5±3.2	0.4
	5-8	42.1±5.3	1.1	8.1±3.5	1.6
Aek	8-11.5	44.5±6.7	1.5	8.5±2.7	0.2
	11.5-16	40.9±5.2	2.6±1.9	6.0±1.9	0.4
	16-20.5	40.2±6.9	1.2	7.4±2.8	0.6
Btk	20.5-24	47.9±6.1	0.2	7.4±2.5	0.5
	24-27	45.2±5.1	0.1	9.5±3.1	0.2
	27-30	39.2±4.3	0.8	9.1±2.8	0.9
Ck	30-34	28.9±7.1	13.9±5.8	7.8±4.1	0.1

Table 4. Means and standard deviations of micromorphological constituents (grouped according to depth) in a Calcareous Brunisolic Gray Luvisol.

Calcareous Brunisolic Gray Luvisol

	Plasma			Pores		
Glaebules	F.G.C.	Second. Carbonate	Other	Ortho	Meta	Organic Frag.
1.6	18.2±2.5	0.1	2.9±1.9	23.1±6.2	5.0±2.3	3.8±3.0
0.6	15.4±4.5	0.5	12.8±4.8	20.4±5.1	3.4±2.6	2.9±2.6
3.1±2.1	11.1±2.9	1.4	2.8±1.9	27.4±3.8	0.1	1.2
1.8	10.0±2.6	3.1±3.6	2.6±2.0	26.8±6.8	0.4	0.9
4.2±3.6	6.4±2.9	3.4±2.6	4.5±2.9	27.8±4.8	0.4	3.6±2.8
5.0±2.5	7.6±2.3	3.8±3.1	5.5±2.9	25.1±5.4	0.0	3.5±2.8
2.5±1.9	15.1±3.3	0.6	0.9	19.9±5.1	4.9±2.3	0.4
3.5±3.1	15.8±3.6	0.1	1.0	20.0±4.1	3.9±2.1	1.1
3.9±1.7	15.1±3.5	1.6	4.5±2.4	19.1±6.2	4.5±3.0	0.6
2.5±2.5	0.0	24.8±5.6	1.8	19.4±5.1	0.4	0.6

differentiated into Bmk, Ae2k, and Btk horizons. The "paleo" B stratum is characterized by having approximately 30 - 50 per cent quartz plus feldspar, and 2 - 20 per cent rock fragments, but very low contents of primary carbonates. Plasmic content varies from about 15 - 30 per cent but is generally about 20 per cent. Approximately 50 - 70 per cent of the plasma in this layer exists as free grain cutans in the upper portion of the stratum, but in Btk horizons as much as 90 per cent may be organized into free grain cutans. Glaebules and iron nodules may account for up to 8 per cent of the soil. Fragmental organic matter content is generally very low, except for the 11 - 20 inch depth of the Calcareous Brunisolic Gray Luvisol. The increase in organic fragments here is coincidental to the presence of a weakly expressed, buried Ahk horizon recognizable in the field. Total pore space varies from 20 - 30 per cent but centers around 25 per cent. The greatest incidence of meta pores is in Btk and Bmk horizons.

Ck horizons of the soils are characterized by the presence of 30 - 40 per cent quartz plus feldspar, 10 - 15 per cent primary carbonates, and 5 - 20 per cent rock fragments. Exclusive of secondary carbonates, total plasma varies from about 2 - 15 per cent of which only minor amounts are organized into free grain cutans. Secondary carbonate content varies among the profiles and can be as high as 30 per cent; the greatest portion of this is in the cryptocrystalline form. It is not uncommon to find iron nodules in the Ck horizon, but their occurrence is generally quite low, as is the content of organic fragments. Pore space varies from 15 - 25 per cent and pores are almost exclusively of the ortho variety.

Confidence limits were calculated for constituents whose incidence

was greater than 2.5 per cent. In most cases the limits for duplicate thin section means, grouped according to depth, was equal to or less than the maximal limits of individual sections. This indicated that variability within sections could be as great as or greater than the variability between sections.

Cumulative percentage plots were prepared for each profile, and are shown in Figs. 4, 5, 6, and 7. These plots are intended to supplement Tables 2, 3, and 4, as well as to summarize information contained in the tables. In reading these plots it should be remembered that they constitute a type of volumetric expression, and that a disproportionate increase in one constituent causes corresponding decreases in other constituents.

Total plasmic distribution with depth is quite variable, and is often highest in the upper part of the "paleo" B horizon. Lowest plasmic contents are in Ck horizons in all soils except the Calcareous Brunisolic Gray Luvisol. In this latter soil, however, plasma is made up predominantly of secondary carbonates. The large increase in plasmic content coincident with the Btk horizon in Fig. 6 is probably indicative of considerable amounts of plasmic illuviation. A corresponding increase is not evident in Fig. 7 but it is conceivable that a certain amount of illuviation has occurred in this soil as well. Plasmic organization in the form of free grain cutans increases gradually to a single maximum in Figs. 4 and 5 corresponding to Bmk horizons, but to a double maxima in Figs. 6 and 7 corresponding to Bmk and Btk horizons. The distribution of meta pores follows the pattern of free grain cutans very closely.

Distribution of skeletal constituents throughout the "paleo" B

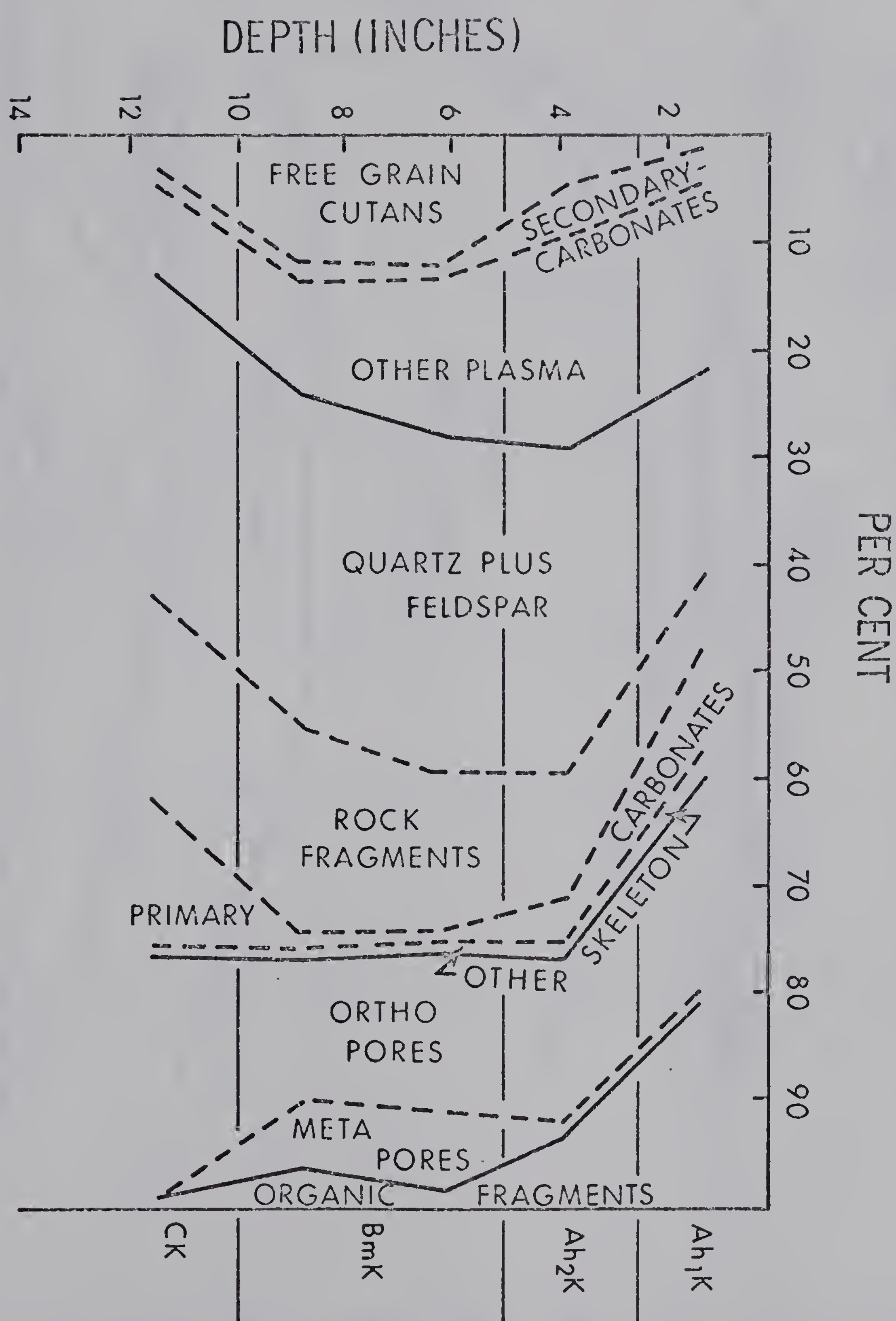

Fig. 4. Variation of fabric constituents with depth in a Calcareous Orthic Moder Melanic Brunisol (expressed as cumulative percentages).

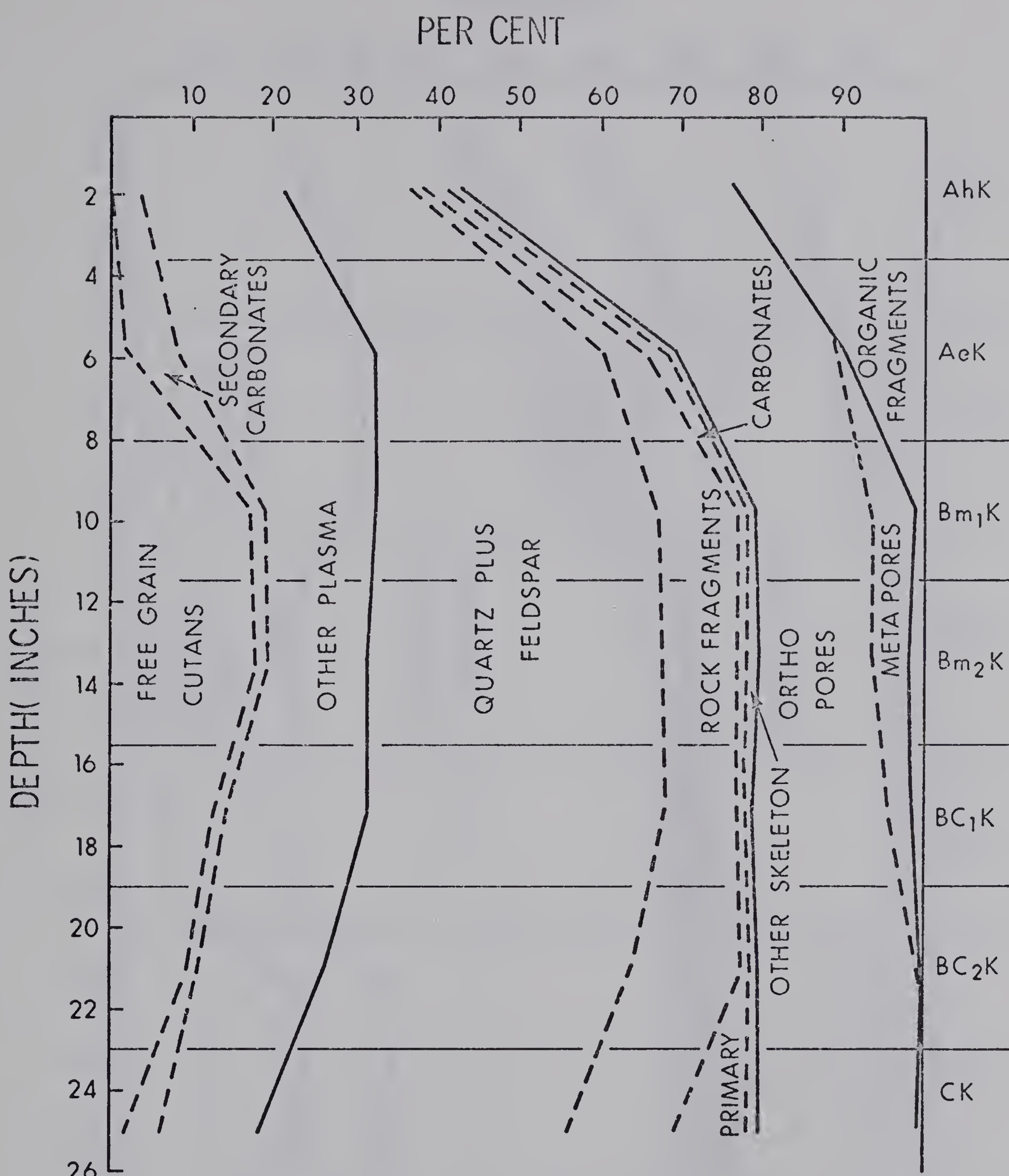

Fig. 5. Variation of fabric constituents with depth in a Calcareous Degraded Moder Melanic Brunisol (expressed as cumulative percentages).

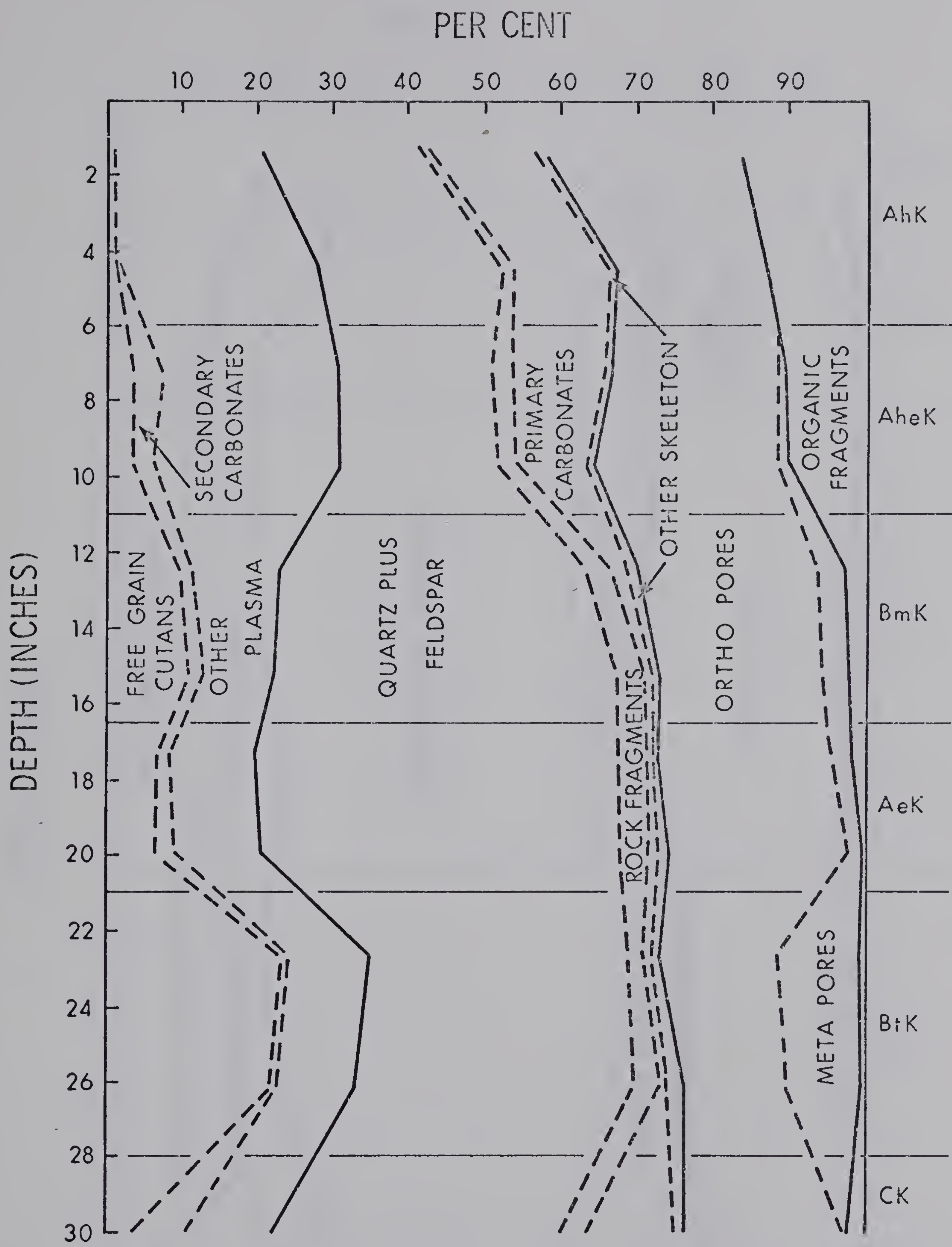

Fig. 6. Variation of fabric constituents with depth in a Calcareous Brunisolic Moder Gray Brown Luvisol (expressed as cumulative percentages).

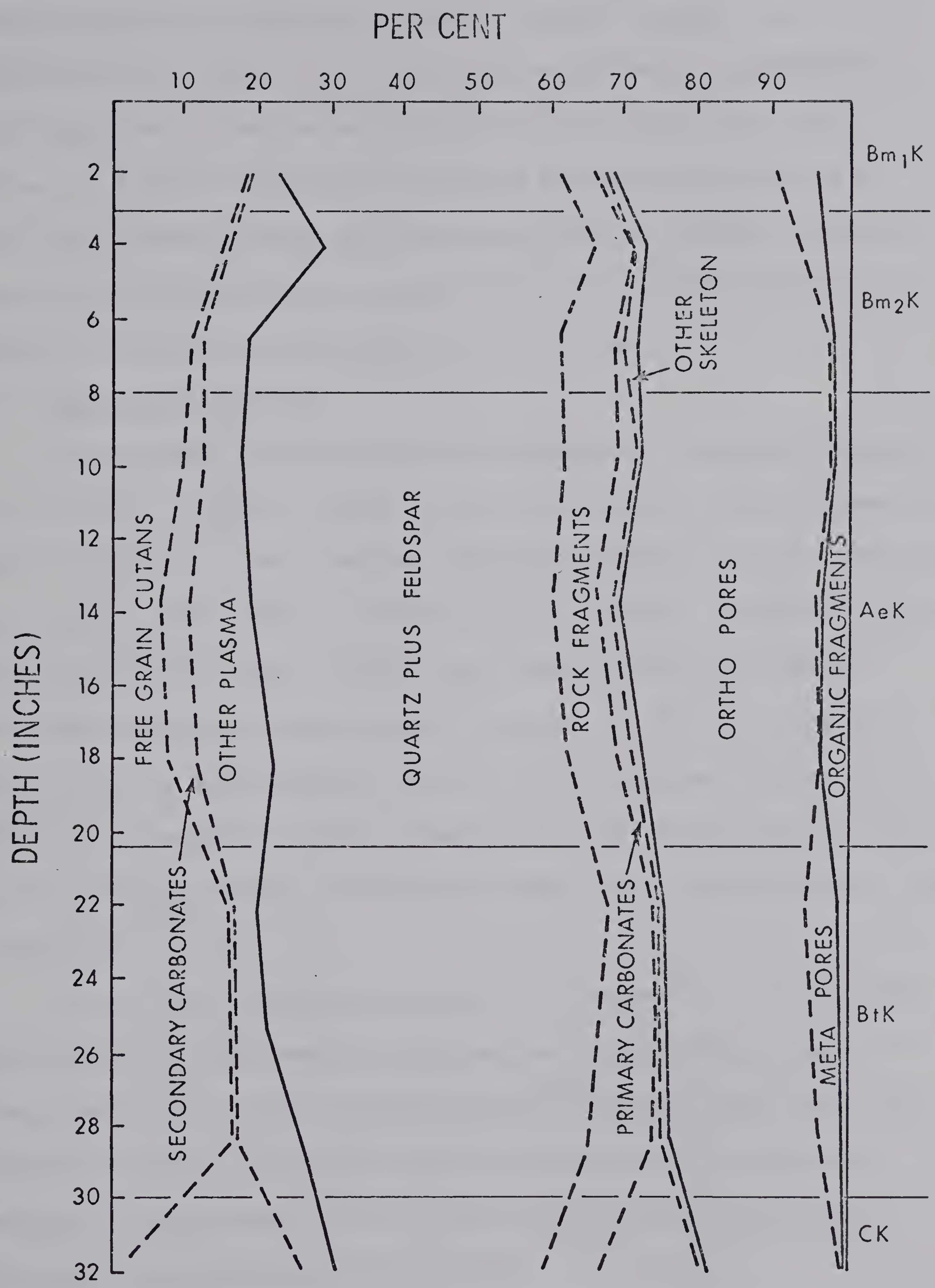

Fig. 7. Variation of fabric constituents with depth in a Calcareous Brunisolic Gray Luvisol (expressed as cumulative percentages).

horizon is quite uniform (except in Fig. 6) but total contents are usually considerably lower in humified, surface horizons, and slightly higher in Ck horizons. Such a distribution indicates the possibility that deposition of aeolian material was not concurrent with soil formation, but that the surface, humified horizons are materials of more recent origin, having been deposited after the "paleo" B horizon was formed. Field evidence, as well as the distribution with depth of primary carbonates, corroborates this observation.

a. Statistical Analyses

Various fabric constituents were selected for statistical analyses in an effort to determine which, if any, constituents were pertinent to specific fabrics. Apart from the grouping of skeletal constituents into one category called "total skeleton" all constituents recognized in the modal analyses were used. Fabric means were derived by arranging individual values obtained by point counting. In addition, the chi-square test for independence, using a 4 X 10 contingency table, and an analysis of variance were run. Homogeneity among individual means was determined using Duncan's New Multiple Range test. The results are shown in Table 5.

The test for independence yielded a chi-square value of 378.17** and indicated a large amount of interaction between fabric types and their constituents. This suggested that the fabrics under study were either the result of absolute amounts of constituents, or that the amounts of constituents within a fabric are the result of processes pertinent to the formation of the fabric.

A cursory insight into this problem was provided through the application of Duncan's New Multiple Range test (Table 5). The amount

Table 5. Fabric means (%), analysis of variance and Duncan's New Multiple Range test ($P < 0.05$) on selected fabric constituents (underlined means are not significant).

Total Skeleton:	Md.[1]	Chl.[2]	Chl. Ag.[3]	Rd.[4]	F=17.95**
	33.5	48.6	49.2	56.5	
Total Plasma:	Rd.	Chl.Ag.	Md.	Chl.	F=1.03
	20.1	24.6	25.5	26.0	
Glaebules & Iron Nodules:	Rd	Chl.Ag.	Md.	Chl.	F=0.90
	1.1	1.4	1.7	2.3	
Free Grain Cutans:	Md.	Rd.	Chl.Ag.	Chl.	F=22.30**
	1.7	1.8	10.4	17.8	
Secondary Carbonates:	Chl.	Chl.Ag.	Md.	Rd.	F=5.36**
	0.7	2.0	2.0	9.4	
"Other" Plasma	Chl.	Rd.	Chl.Ag.	Md.	F=9.09**
	5.1	7.8	10.8	20.2	
Total Pores:	Rd.	Chl.Ag.	Chl.	Md.	F=1.24
	21.1	23.4	24.3	24.6	
Ortho Pores:	Chl.	Chl.Ag.	Rd.	Md.	F=3.04*
	17.4	20.6	20.9	24.2	
Meta Pores:	Rd.	Md.	Chl.Ag.	Chl.	F=9.66**
	0.2	0.4	2.8	6.9	
Organic Fragments	Chl.	Rd.	Chl.Ag.	Md.	F=36.14**
	1.0	1.7	2.8	15.6	

1. Calcareous Rendzina Moder and Calcareous Mull-like Rendzina Moder Fabric (6 replicates).

2. Calcareous Chlamydomorphic Fabric (5 replicates).

3. Calcareous Chlamydomorphic Agglomeratic Fabric (18 replicates).

4. Calcareous Chlamydomorphic Rendzina Fabric (4 replicates).

of total skeleton was significant among all fabrics except between the Chlamydomorphic and Chlamydomorphic Agglomeratic types; visual observations indicated these latter two fabrics to be subtypes of each other. Although the difference in total plasma content among fabric types was not indicated as being significant, the organization and character of the plasma, as indicated by the content of free grain cutans, secondary carbonates and "other" (unorganized) plasma, was significant. As might be expected, the means for free grain cutans in Chlamydomorphic and Chlamydomorphic Agglomeratic fabrics were significantly different from the means of the other two fabrics; the content of secondary carbonates was significant only for Rendzina fabrics; the amount of "other" plasma was significant for only Moder fabrics; recognizable iron content (glaebular and nodular) was not significant. In the same way, total pore space proved to be insignificant, but the character of the pore space was important. The content of ortho pores was significantly different for only Moder fabrics, while only Chlamydomorphic fabrics had significantly different contents of meta pores. Content of organic fragments was characteristic for only Moder fabrics.

These results indicate that pedogenic processes operative at a micro-site are primarily responsible for the character of the soil fabrics under study. As indicated by the total skeletal contents, however, the make-up of the media on which pedogenesis occurs cannot be overlooked, since this could have an adjuvant effect on the resultant fabric. Similar views had been proposed earlier (Dumanski, 1964).

Linear correlation coefficients calculated for selected groups of constituents are shown in Table 6. The data indicate highly significant

correlations between free grain cutans and meta pores for all soils studied. Correlations between free grain cutans and ortho pores, however, were significant only in soils having Ahk horizons. Free grain cutans and glaebules (plus iron nodules) showed no significant correlations, indicating that iron need not segregate in a soil but can remain interspersed throughout the plasma. Correlations between quartz plus feldspar and rock fragments were significant and highly significant for soils having Ahk horizons but not for the Calcareous Brunisolic Gray Luvisol. This may reflect selective wind sorting with distance from the source area, since the location of the latter soil was approximately twice the distance compared to the former three soils. Primary carbonates versus secondary carbonates showed a significant correlation only in the Calcareous Degraded Moder Melanic Brunisol, but a highly significant correlation in the Calcareous Brunisolic Gray Luvisol. Organic fragments correlated with "other" plasma only in the Calcareous Brunisolic Moder Gray Brown Luvisol.

Of particular interest are the correlations between free grain cutans and meta pores, and between primary and secondary carbonates. The first case illustrates the effect of both plasmic organization and quantity of plasma on development of meta pores. Meta pores are common in all Bmk horizons, but their incidence is greatest in Btk horizons. These latter horizons show the highest amounts of organized plasma and are zones of accumulation of translocated plasma. As illuviation of plasma progresses over time, it is conceivable that at a particular clay content, free grain cutans begin to assume morphologies indicative of intergranular braces. In these local areas contraction of soil solutions upon drying lines the pore walls with

Table 6. Linear correlation coefficients calculated for selected pairs of constituents. Significance levels taken from Steele and Torrie (1960).

	Calcareous Orthic Moder Melanic Brunisol	Calcareous Degraded Moder Melanic Brunisol	Calcareous Brunisolic Moder Gray Brown Luvisol	Calcareous Brunisolic Gray Luvisol
free grain cutans vs meta pores	0.98**	0.92**	0.99**	0.82**
free grain cutans vs ortho pores	-0.85*	-0.81*	-0.75**	-0.25
free grain cutans vs glaebules	-0.10	-0.18	-0.54	-0.32
quartz and feldspar vs rock fragments	0.80*	0.90**	0.82**	0.26
primary carbonates vs secondary carbonates	0.44	0.70*	0.19	0.99**
"other" plasma vs organic fragments	0.51	0.51	0.88**	0.49

clay, thereby converting ortho pores to meta pores. In such cases, these pores could be used as proof of illuviation.

The correlation between primary and secondary carbonates as indicated in Table 6 is significant for only two soils. However, when the Ahk horizons are disregarded, similar correlations determined over the "paleo" B and Ck horizons invariably show increased values to greater than 0.95. This indicates that primary carbonates are probably the exclusive source for secondary carbonates. Coupling this with field observations, it becomes evident that weathering of carbonates and translocation in solution results in initial carbonate precipitation within Ahk horizons. Such illuviation may be due to lithologic changes in the nature of the material, and/or is a

reflection of the depth of penetration of the most common rain showers. Subsequent resolution results in the transportation of major portions of the carbonate ions directly to the Ck horizon. Minor amounts, however, may crystallize within the solum at points where local desiccation would saturate soil solutions.

Soil Characterization Analyses on Monolith Samples

Analyses identical to those described under "Routine Analyses on Bulk Samples" were conducted, in duplicate, on disturbed samples taken from regions contiguous to those from which duplicate thin sections were obtained. These studies were originated to determine possible variations of components with depth and to study factors which may be instrumental in fabric development. Individual means are shown in the Appendix, but plots showing the variation of chemical constituents with depth are presented in Fig. 8. Cumulative percentage plots showing the variation of particle size constituents with depth are given in Fig. 9.

Soils having humified surface horizons show gradual decreases in organic carbon and total nitrogen content with depth. Calcium carbonate equivalent, on the other hand, shows a type of hyperbolic distribution, being highest in surface and Ck horizons, and decreasing to a minimum (but never to zero) in the "paleo" B horizon. The absolute thickness of the "paleo" B horizon controls the overall shape of the curve.

The two types of iron distribution curves are of particular interest. McKeague and Day (1966) state that oxalate extractable iron represents only amorphous forms of hydrated iron oxides in the soil, although later studies have shown that it may extract magnetite

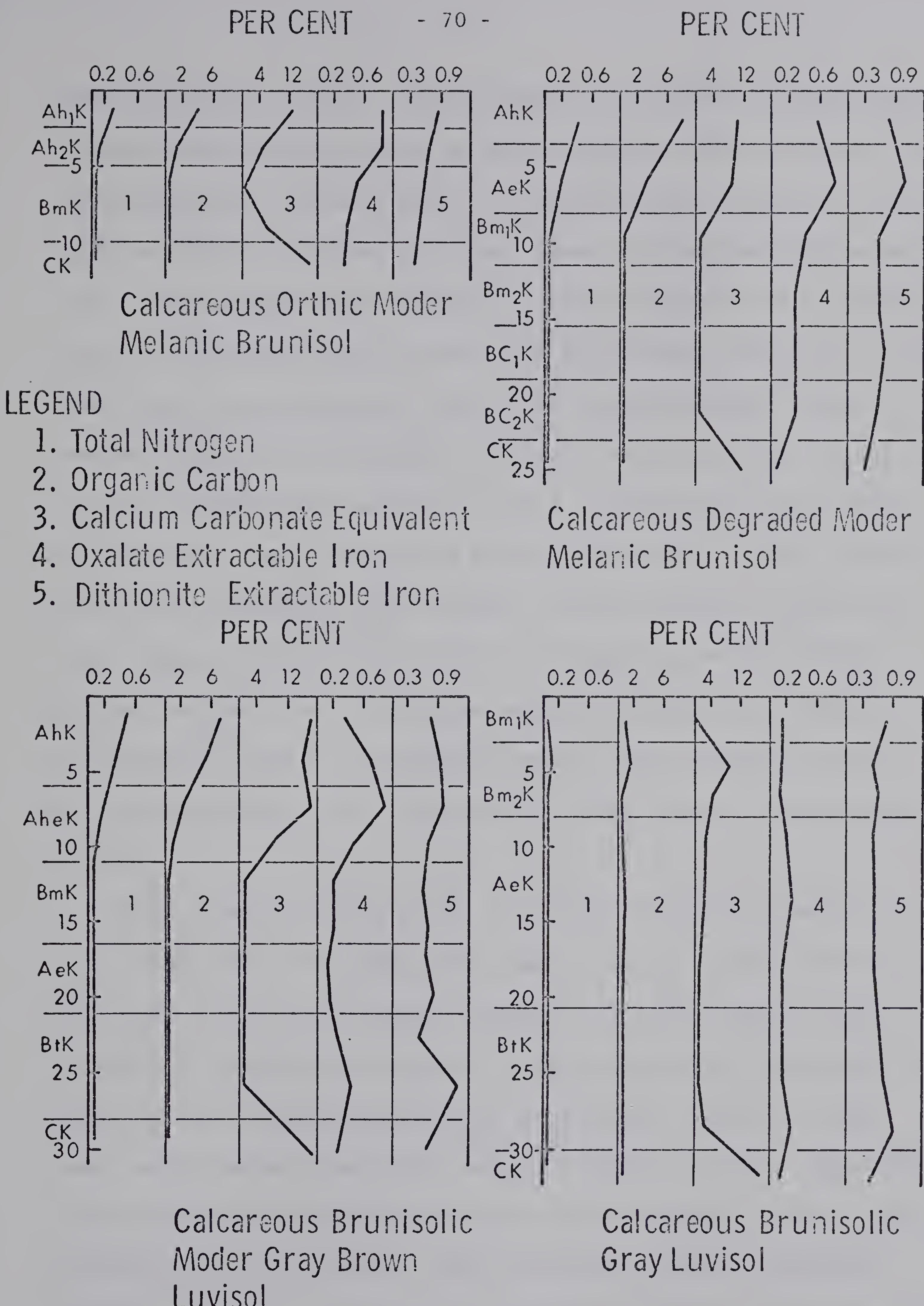

Fig. 8. Variation of chemical constituents with depth (inches).

(Baril and Bitton, 1969). Sodium dithionite is known to extract both amorphous hydrated iron oxides as well as some of the crystalline iron oxides (Mehra and Jackson, 1959). As shown in Fig. 8 content of iron oxide extracted by the two procedures shows a strong parallelism with depth. This suggests that either the two extractants remove the same types of iron oxides from the soil, but that sodium dithionite is more effective, or that amorphous and crystalline forms present have similar ratios for all horizons. Further, free iron oxides appear to increase gradually to a maximum at the 4 - 8 inch depth after which they decrease. Soils containing Btk horizons show a further increase in the lower portions of this horizon. Modal analysis revealed the upper maximum, but failed to detect the "bump" in the Btk horizon. This may indicate that iron oxides collect as nodules and glaebules in surface horizons but precipitate as iron flow structures in the Btk. In the latter case, this would have been counted as free grain cutans.

Cumulative percentage plots, indicating variation of particle size constituents with depth, are shown in Fig. 9. Except for the Calcareous Orthic Moder Melanic Brunisol, all soils below the Ahk horizon are characterized by low to very low contents of particles coarser than fine sand, approximately equal and moderate contents of fine sand, very fine sand, and silt, and low contents of clay. Ahk horizons, on the other hand, are characterized by a predominance of silt-sized particles, low clay contents, and sand contents that are generally lower than those in the underlying "paleo" B horizon. This is further testimony to the incompatibility of this material with that found in the "paleo" B horizon.

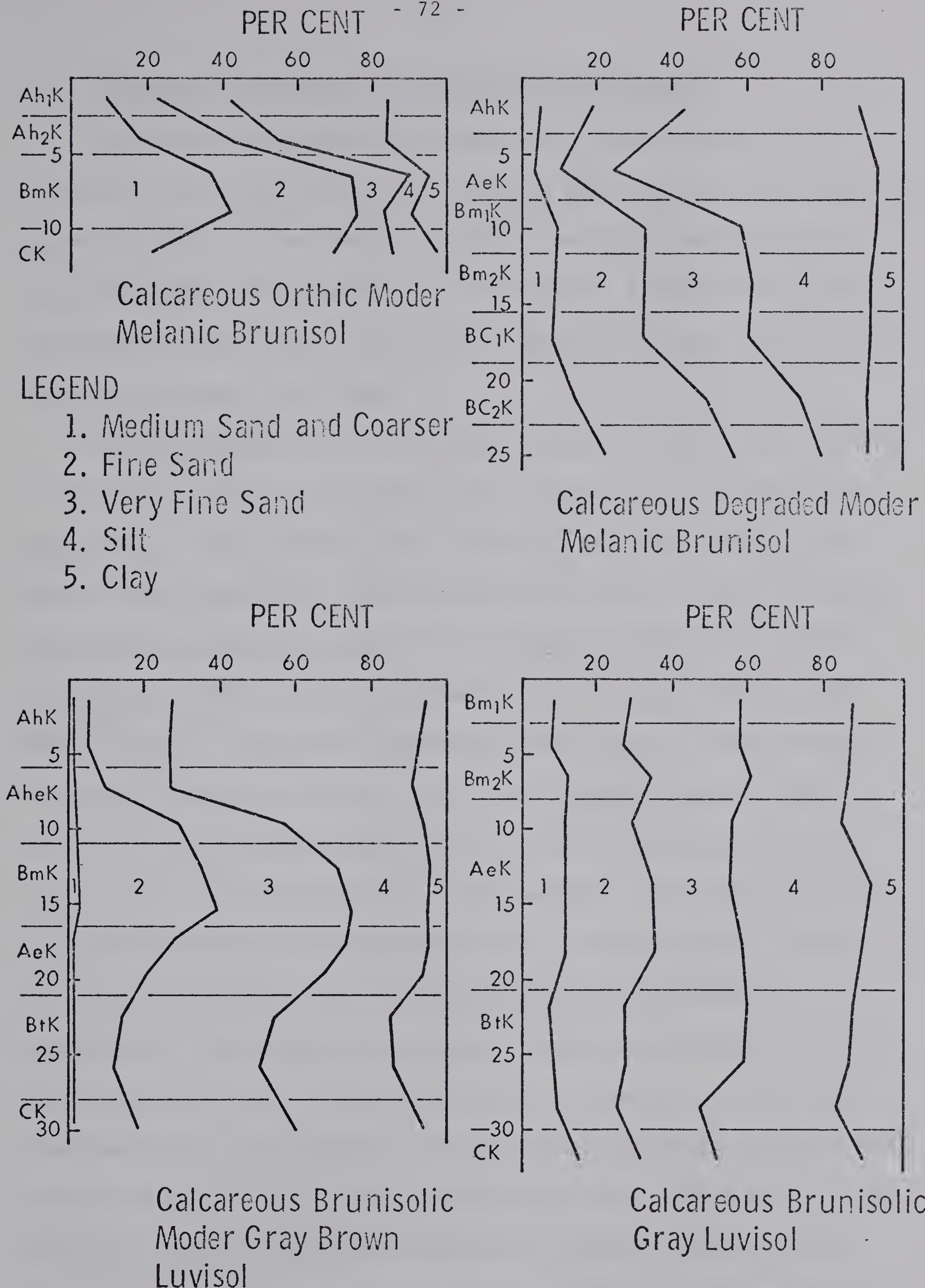

Fig. 9. Variation of skeletal constituents with depth (inches), expressed as cumulative percentages.

a. Statistical Analyses in Relation to Soil Fabrics

Since disturbed samples were taken from regions immediately adjacent to areas from which thin sections were obtained, the analytical characterization of the samples served as an approximation of the chemical and physical composition of a fabric. Results were grouped according to fabric type, and analyzed using the F-test, and Duncan's New Multiple Range test (Table 7).

Several variables listed in Table 7 appear to be related directly to deposition, thereby precluding their usefulness as indicators of pedogenesis. These include total sand and total silt, and to some degree $CaCO_3$ equivalent, total nitrogen, and organic carbon. Oxalate extractable aluminum content is statistically insignificant amongst all fabrics, while oxalate extractable iron is significant for only Moder fabrics. Dithionite extractable iron content is significantly different for all soil fabrics except for Chlamydomorphic vs Moder fabrics. Since Chlamydomorphic fabrics are characteristic of only Btk horizons, and Moder fabrics of Ahk horizons, this then indicates a two stage process of iron translocation. If one assumes that all iron oxides originate from primary carbonates, then initial precipitation takes place close to the sites of weathering, i.e. within the Ahk horizons. If the precipitates are associated with either humic materials or secondary carbonates, then subsequent solution and release is possible, in which case reprecipitation takes place in Btk horizons. Accretionary growth within Btk horizons results in the formation of iron flow structures. This process could be maintained as long as the supply of carbonates to the surface of the profile was continued.

Table 7. Means, analysis of variance, and Duncan's New Multiple Range test ($P < 0.05$) for analytical variables in relation to soil fabrics.

pH:	Chl.[1]	Chl.Ag.[2]	Md.[3]	Rd.[4]	F=2.35
	7.9	8.0	8.1	8.2	
$\%CaCO_3$ Eq.:	Chl.	ChlAg.	Md.	Rd.	F=41.53**
	1.00	2.85	14.35	17.28	
% Total N:	Chl.	Rd.	Chl.Ag.	Md.	F=21.46**
	0.03	0.04	0.06	0.32	
% Organic C:	Chl.	Rd.	Chl.Ag.	Md.	F=16.62**
	0.22	0.57	0.67	4.80	
% Oxalate Ext. Fe:	Rd.	Chl.	Chl.Ag.	Md.	F=6.13**
	0.22	0.26	0.32	0.64	
% Oxalate Ext. Al:	Rd.	Chl.	Chl.Ag.	Md.	F=1.09
	0.08	0.12	0.18	0.18	
% Dithionite Ext. Fe:	Rd.	Chl.Ag.	Chl.	Md.	F=6.50**
	0.46	0.65	0.83	0.85	
% Dithionite Ext. Al:	Rd.	Chl.Ag.	Chl.	Md.	F=7.62**
	0.02	0.03	0.04	0.09	
% Total Sand:	Md.	Chl.	Chl.Ag.	Rd.	F=6.82**
	37.5	54.4	63.8	69.2	
% Total Silt:	Rd.	Chl.Ag.	Chl.	Md.	F=6.51**
	24.0	27.9	31.8	53.2	
% Total Clay ($<2.0\ \mu$):	Rd.	Chl.Ag.	Md.	Chl.	F=4.12*
	6.8	8.4	9.2	13.4	
% Fine Clay ($<0.2\ \mu$):	Md.	Rd.	Chl.Ag.	Chl.	F=5.29**
	3.2	4.0	4.4	7.4	

1. Calcareous Chlamydomorphic Fabric (5 replicates).

2. Calcareous Chlamydomorphic Agglomeratic Fabric (18 replicates).

3. Calcareous Rendzina Moder and Calcareous Mull-like Rendzina Moder Fabric (6 replicates).

4. Calcareous Chlamydomorphic Rendzina Fabric (4 replicates).

Other indicators of pedologic translocation are the total clay and fine clay fractions. The contents of both constituents are significantly different for only Chlamydomorphic fabrics which, as mentioned previously, are coincident to Btk horizons. This testifies to the fact that clay translocation has occurred in these soils in spite of the presence of secondary carbonates.

Clay Mineralogy

Coarse clay (2.0 - 0.2 μ) and fine clay ($<$0.2 μ) fractions were collected from samples identical to those in the preceding section, and were used to characterize the clay mineral composition. Both X-ray and differential thermal techniques were used.

Fig. 10 shows X-ray diffractograms of fine and coarse clays from the Calcareous Orthic Moder Melanic Brunisol. These are relatively representative of patterns obtained for all samples analyzed.

The X-ray data indicated that the mineral assemblage of all samples was practically identical. All coarse clays contained 14 Å interstratified montmorillonite (air-dry) which expanded to 16.7 Å upon treatment with ethylene glycol, and contracted to 10 Å upon heating to 550°C. In addition to this, significant amounts of quartz, chlorite, and illite, as well as lesser amounts of kaolinite, were present. Feldspars and carbonates were sometimes detectable in trace amounts. Fine clays were dominated by interstratified montmorillonite, but detectable amounts of illite and quartz were also present. Occasionally kaolinite and chlorite could be detected. Clay mineral interstratification appeared to be of the montmorillonite-chlorite-illite type with a predominance of montmorillonite.

The distribution of clay minerals with depth was generally

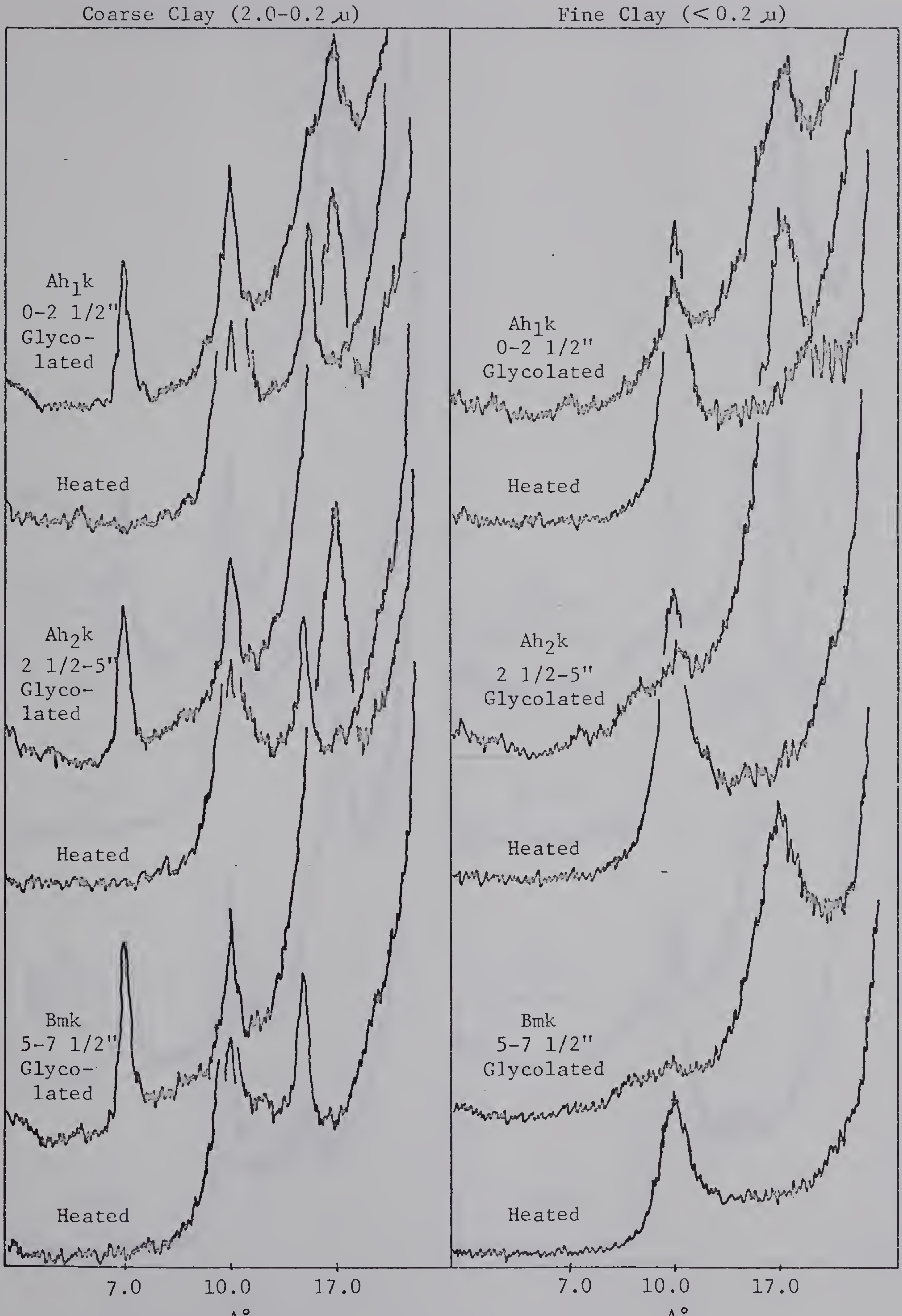

Fig. 10. X-ray diffraction patterns of clay material separated from the Calcareous Orthic Moder Melanic Brunisol.

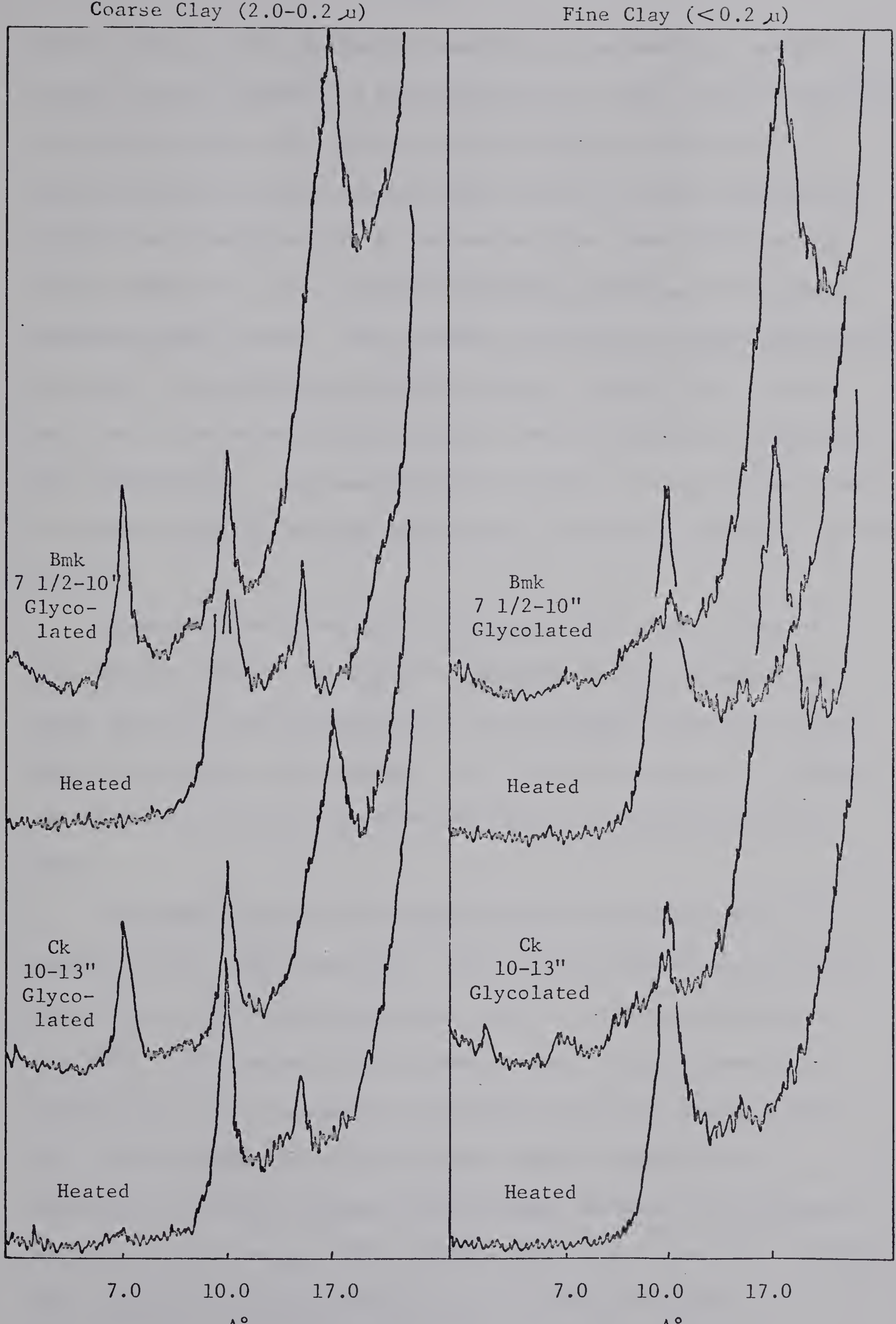

Fig. 10. X-ray diffraction patterns of clay material separated from the Calcareous Orthic Moder Melanic Brunisol.

quite uniform but the following anomalies are noteworthy. Both the height and the sharpness of the montmorillonite peak tended to increase with depth, within the confines of Ahk horizons. Additional extractions with neutral sodium citrate failed to alter the patterns significantly and therefore it was assumed that these features were either inherited or were caused by partial interlaying with strongly adsorbed organic matter. Btk horizons, on occasion, showed quantitative increases in montmorillonite and/or illite. Whether such increases were due to preferential illuviation or were a function of deposition was indeterminate. Semi-quantitative estimates of clay content, based on visual appraisals of peak intensities, are shown in Table A28 of the Appendix.

Representative differential thermographs are shown in Fig. 11. Only samples from the Calcareous Orthic Moder Melanic Brunisol and those from the lower solum and Ck of the Calcareous Brunisolic Moder Gray Brown Luvisol were analyzed. The results were generally similar, and there was little discernible difference as a result of particle size.

All samples showed fairly distinct low temperature peaks in the ranges of 120^{o} - $150^{o}C$ and 200^{o} - $230^{o}C$, which could be attributed to the loss of adsorbed water (Jackson, 1956). The broad exotherm in the 300^{o} - $350^{o}C$ range, which is most intense in Ahk horizons, is probably due to the oxidation of strongly associated organic matter (St. Arnaud and Mortland, 1963), which tends to adhere to clay particles even after treatment with hydrogen peroxide. The hydroxyl endotherm occurs between 560^{o} - $590^{o}C$. This peak may be due to illite (St. Arnaud and Mortland, 1963), iron-rich montmorillonite, or

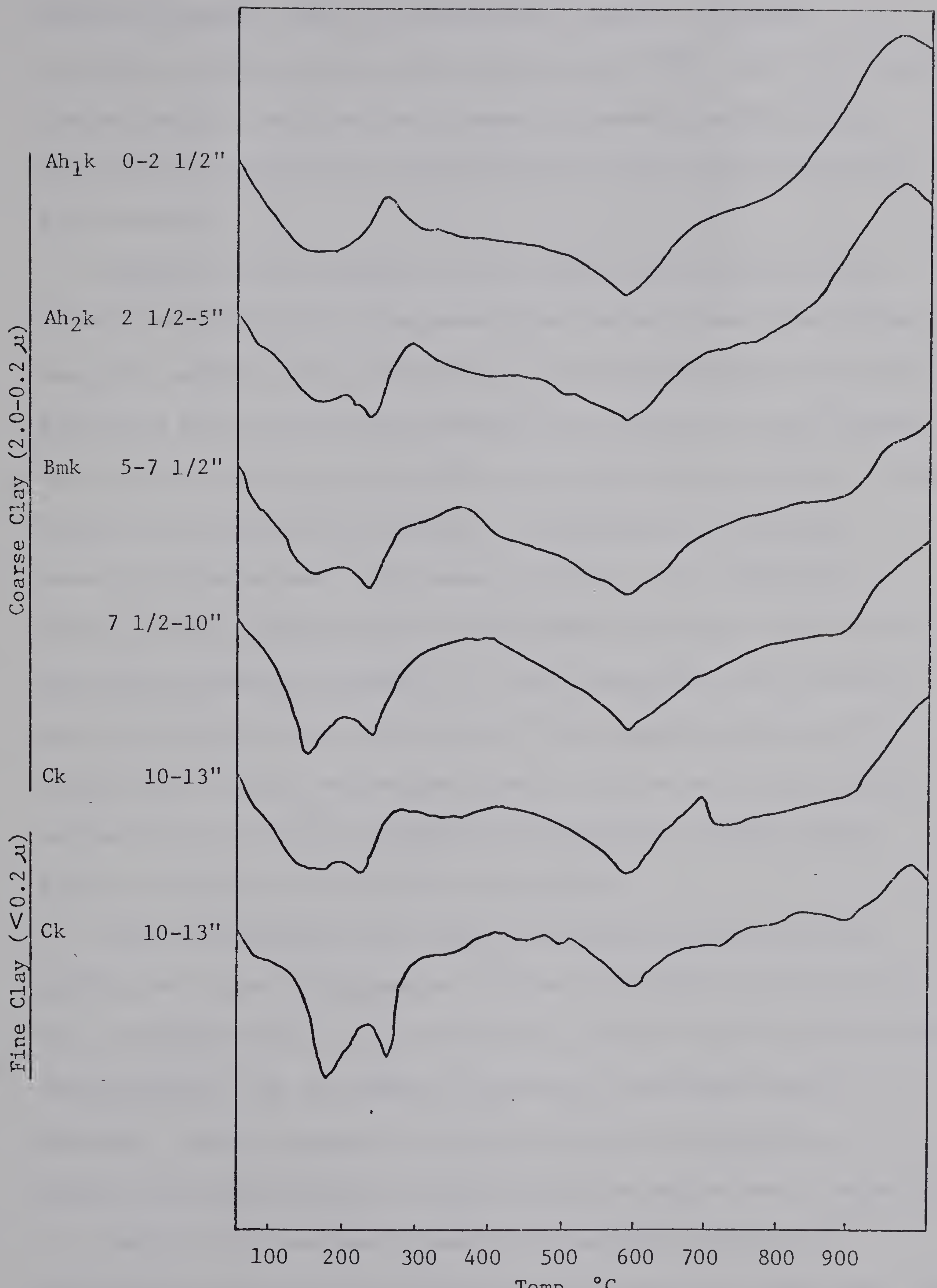

Fig. 11. Differential thermographs of clay material from the Calcareous Orthic Moder Melanic Brunisol.

chlorite (Jackson, 1956), or combinations thereof. A slight exothermic reaction occurs in the region above 900°C. Thus differential thermal analysis indicates the presence of montmorillonite, illite, and chlorite, and generally corroborates the observations from using X-ray analyses.

Estimates of the amounts of illite and montmorillonite present in the fine clay fraction (separated from the Calcareous Moder Melanic Brunisol, and from the lower solum and Ck of the Calcareous Brunisolic Moder Gray Brown Luvisol) were calculated on the basis of K_2O content and surface area determinations (St. Arnaud and Mortland, 1963). Illite content was determined by assigning all potassium to illite and assuming illite to have a K_2O content of 10 per cent (Mehra and Jackson, 1959). Having calculated the amount of illite, a portion of the surface area was assigned to it, thus permitting one to estimate montmorillonite content on the basis of the remaining portion of the surface area. Illite and montmorillonite were assumed to have total surface areas of 10 m^2/g and 980 m^2/g respectively (Twardy, 1969). Results are shown in Table A29 in the Appendix.

Illite distribution with depth is irregular in the Brunisolic profile, but shows a progressive increase with depth in the Luvisolic soil. Montmorillonite, on the other hand, shows irregular distribution in the Luvisol, but its content is greatest in the Bmk horizon of the Brunisol. Since no regular eluviation pattern is discernible, it is likely that major portions of this distribution may be due to deposition.

Particle size analyses, shown in the Appendix, indicate a preferential translocation of fine clay in relation to coarse clay. This suggests that montmorillonite and illite probably move together.

Similar observations were reported by St. Arnaud and Mortland (1963).

Illite contents, are somewhat higher than would be expected from X-ray analysis. This indicates possible contamination from primary minerals, especially potassium feldspars. If this is the case, then the calculations may be considered only as approximations. This form of contamination is considerably more serious if similar calculations are carried out for coarse clays (shown in the Appendix) since X-ray analysis indicates the presence of feldspars in many samples. However, use of the calculation indicates that montmorillonite and illite account for somewhat less than 70 per cent of the weight of the coarse clay fraction. The ratio of occurrence of montmorillonite to illite varies from 1:1 in the Brunisol to 1:3 in the Luvisol. These ratios remain relatively constant throughout the depth of the profile.

Free Grain Petrographic Analyses

The fine sand fraction (0.10 - 0.25 mm) was used for detailed petrographic analysis, the purpose of which was to check the lithologic uniformity of the aeolian material. The samples were divided into three fractions on the basis of specific gravity (<2.40; $2.40 - 2.96$; >2.96), after which individual grains were identified and counted. The counts per slide were subdivided to give a total of 400 points per soil horizon. A composite sample was taken from the vicinity of Jasper Lake and used as a reference. All pertinent data are contained in the Appendix.

Grains in the s.g. 2.40 - 2.96 group account for 93 - 99 per cent of the total weight of the fine sand fraction; lowest contents are in the humified, surface horizons below which distribution with depth is quite uniform. The fraction of s.g. >2.96 make up about 1 per cent of the fine sand fraction. Comparing contents within each profile indicates

that humified, surface horizons are consistently lower in heavy minerals than those in "paleo" B horizons. This further testifies to the discontinuity between surface horizons and those within the "paleo" B. The content of the very light mineral fraction (s.g. $<$ 2.40) varies from 0.03 - 3.39 per cent, and its distribution with depth is irregular. This suggests the presence of volcanic ash layers.

a. Very Light Minerals (s.g. $<$ 2.40)

This fraction is dominated by a colorless, biaxial positive, quartz-like constituent which is irregular in shape. Refractive index is less than 1.54, extinction is instantaneous and included tubules and veins can sometimes be observed. The inferred volcanic origin and low specific gravity suggest that these grains are cristobalite and/or tridymite (Berry and Mason, 1959; Moorhouse, 1959). In general, contents of these grains are lower in humified, surface horizons than within "paleo" B horizons.

The contents of volcanic glass and volcanic fragments are variable, and their distribution through depth is irregular. Plate 9 illustrates volcanic ash fragments separated from the soils. This ash is characterized by the presence of pumice fragments in which there are abundant vesicles, tubules, and inclusions. It has been identified* as St. Helen's Y ash whose age has been reported as lying between 2980 $\pm$ 250 and 3500 $\pm$ 250 years B.P. (Westgate and Dreimanis, 1967). This ash was found in some Ahek, Aek, and Bmk horizons at depths ranging between 6 and 20 inches, and therefore has probably been reworked.

Lithologic discontinuities between humified surface horizons and those within the "paleo" B were indicated by this analysis, in that

* J. A. Westgate - personal communication

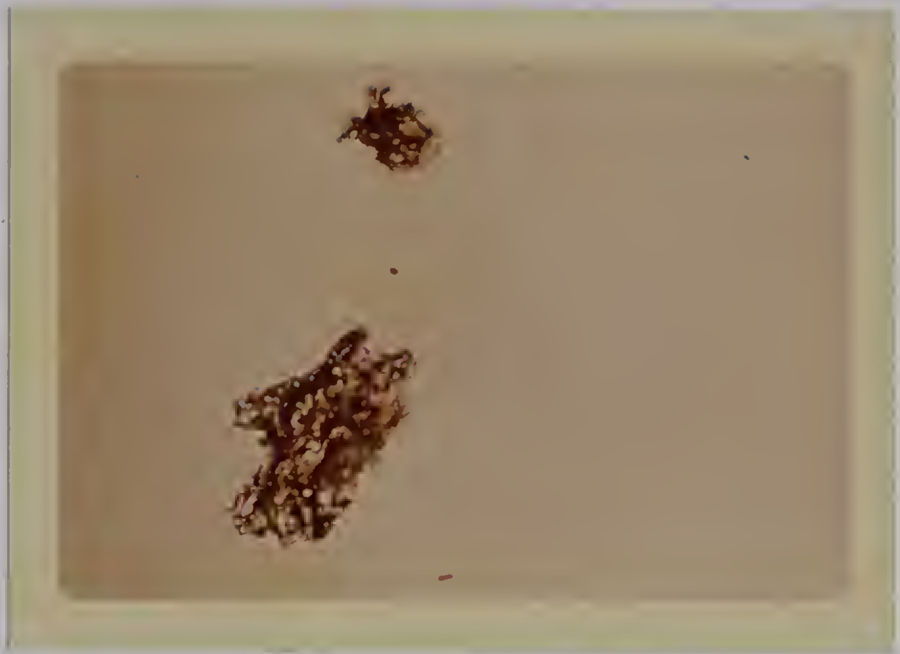

Plate 9. Volcanic glass fragments. Magnification 200X.

surface materials generally had lower contents of rock fragments, and higher contents of charred wood fragments, mineralized roots, and unidentifiable constituents (others). Mineralized roots included fragments with distinct biogenic structure, but in which intracellular material had been replaced by SiO_2 or $CaCO_3$.

b. Light Minerals (s.g. 2.40 - 2.96)

This fraction is dominated by quartz, chert, orthoclase, and rock fragments. The low incidence of primary carbonates probably indicates decomposition by the buffered sodium acetate solution which was originally intended to remove only secondary carbonates. Some of the quartz within this fraction is of volcanic origin.

c. Heavy Minerals (s.g. $>$ 2.96)

The dominant constituents are iron-opaque minerals, which make up from 30 to 55 per cent of the total weight of this fraction. The Cordilleran source of this material is reflected in the moderately high incidence of the chlorite plus chloritoides, and the low content of amphiboles and hornblendes (Roed, 1968). The content of chlorites

and chloritoides is often greatest in surface, humified horizons.

For purposes of checking the uniformity of material throughout a profile, the most dependable minerals are zircon and tourmaline (Brewer, 1964b). With this in mind, the zircon/tourmaline ratios (z/t) were calculated for each horizon, and are shown in Table 8. The results indicate a non-uniform history of deposition, with more similarity within profiles than between profiles.

Table 8. Calculations as to the uniformity of material

Soil	Horizon	Z*/T	C.E.A.VF.**/Z.T.R.	Soil	Horizon	Z/T	C.E.A.VF./Z.T.R.
Calcareous Orthic	Ahk	1.24	1.01	Calcareous Degraded	Ahk	1.64	1.20
Moder Melanic	Bmk	1.75	0.60	Moder Melanic	Aek	1.41	1.40
Brunisol	Ck	1.82	0.80	Brunisol	Bmk	1.62	1.07
					BCk	0.88	1.00
Calcareous Brunisolic	Ahk	0.67	2.51		Ck	0.82	1.26
Moder Gray Brown Luvisol	Ahek	1.17	2.16				
	Bmk	0.97	1.49	Calcareous Brunisolic	Bmk	0.63	5.84
	Aek	0.87	1.61	Gray Luvisol	Aek	0.89	3.47
	Btk	0.72	1.62		Btk	0.74	2.82
	Ck	1.00	1.21		Ck	0.32	2.88

* - Zircon/tourmaline
** - Chlorite & chloritoides plus epidote & zoisite plus amphibole & hornblende plus volcanic fragments/zircon plus tourmaline plus rutile.

To check this observation the sum of the easily weatherable minerals (chlorite plus chloritoide, epidote plus zoisite, amphiboles plus hornblende, and volcanic fragments) was divided by the sum of the highly stable minerals (zircon, tourmaline, rutile). The results shown in

Table 8, in a general way substantiate the non-uniformity of the material. They further indicate that the greatest break in uniformity occurs near the junction of surface humified horizons and the "paleo" B horizon. This consolidates evidence presented in earlier sections as to the youthfulness of the humified horizons. Of additional interest is the fact that the heavy mineral suites in surface horizons reflect the reference material more closely than do those in "paleo" B horizons.

Experimental Micromorphology

a. Experiment 1 - varying amounts of calcium saturated, soil clays were thoroughly mixed into known weights of pure quartzitic sand (Ottawa sand), saturated with distilled water, and then dried at 30^{o}C for 24 hours. Clay contents were progressively increased in proportions of 10, 20, 30, and 40 per cent by weight, and each clay level was duplicated. The wet-dry treatment was repeated 10 times with mixing.

During the course of the wet-dry treatments, it was noticed that thin clay crusts appeared at the surface of the sand columns after the second treatment. This crust reappeared after each subsequent treatment, irrespective of mixing.

Thin section examination revealed that in samples with the lowest clay contents, the plasma existed as microaggregates (30 - 50 μ) which adhered to the surface of grains, or occurred as loose, interskeletal aggregates (Plate 10.1). The aggregates were interconnected around skeletal grains by very thin clay films. As the clay content was increased to 20 per cent there were corresponding increases in the thickness of grain coatings, and in the size of microaggregates (Plate 10.2). Where possible these formed interskeletal braces or even completely filled the smaller interskeletal spaces. Clay increases

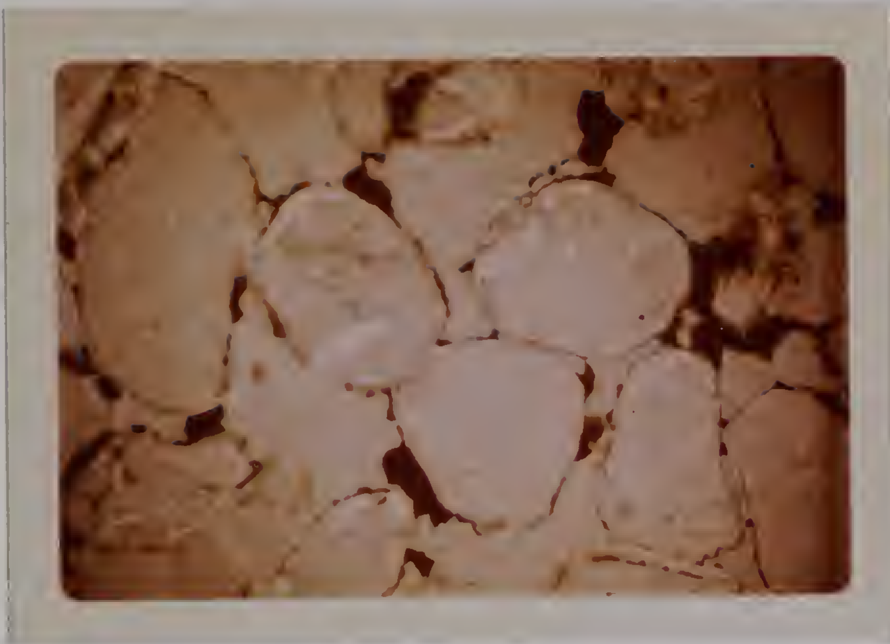

Plate 10.1. Thin clay films and small aggregates adhering to skeleton grains in Experiment 1; 10 per cent clay treatment. Magnification 50X.

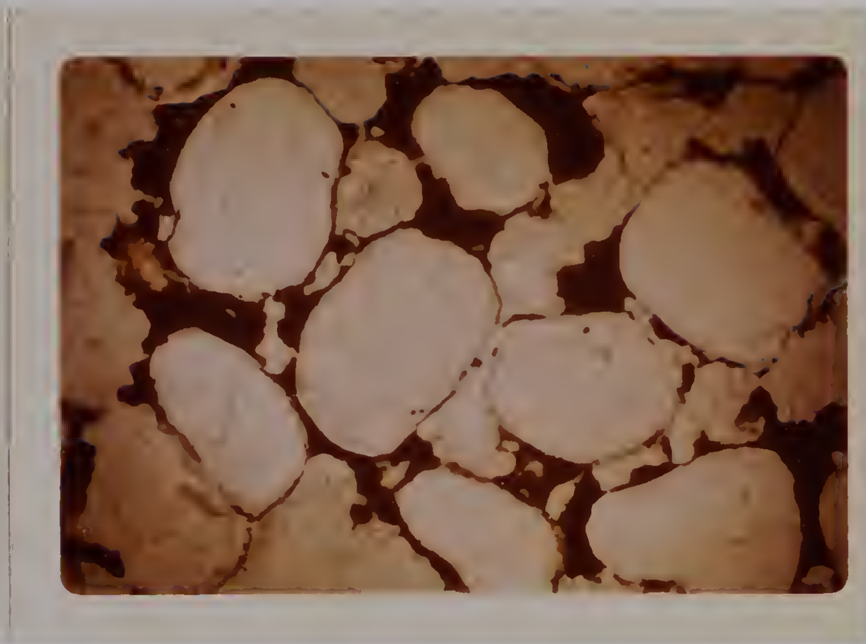

Plate 10.2. Increase in clay aggregate size and well developed interskeleton bridges. Experiment 1; 20 per cent clay treatment. Magnification 50X.

Plate 10.3. Variation of fracture patterns on drying caused by varying clay contents. Experiment 2; per cent clay increases to the right.

Plate 10.4. Size differentiation of silt and clay at the top of a clod due to capillary draft. Experiment 2; 5 per cent clay treatment. Partially crossed nicols. Magnification 50X.

beyond this point merely accentuated this phenomena so that more interskeletal pores were filled, and shrinkage cracks began to appear. In all slides the void pattern was highly irregular.

b. Experiment 2 - varying amounts of calcium saturated, soil clays were added to known weights of sand plus silt premixed in a ratio of 2:1. Sufficient clay was added to give clay percentages of 5, 10, 20, 30, and 40 per cent. The mixtures were then wet and dried 10 times as before.

Thin clay crusts were present in all columns, as in Experiment 1, but were most noticeable in columns with the lower clay contents. Plate 10.3 shows fracture patterns typical of those formed during drying.

Microscopic examination in thin section indicated that in all samples the silt particles tended to completely fill intergranular spaces. Clay materials were oriented around silt grains but also aggregated into equidimensional microaggregates, some of which tended to adhere to skeletal grain surfaces. An increase in clay content increased the size of coatings around silt grains, but failed to produce any sizeable coatings on skeletal grains. This suggests that the presence of an abundant supply of silt-sized material has a disruptive effect on the orientation of plasmic materials around skeletal grains. This is in agreement with the findings of Brewer and Haldane (1957).

Two interesting phenomena were observed in this experiment. In the first case, the movement of moisture towards the surface of evaporation produced a well defined pattern of particle size distribution at the top of the clod (Plate 10.4). Since this occurred with both clay and silt-sized material, then it follows that the finer silt particles should definitely be included in any definition of soil plasma.

This justifies the 10 μ separation used for modal analysis.

The second phenomena concerns the nature of voids. In cases where clay content was 10 per cent or less, the voids were invariably circular and 50 - 150 μ in diameter. When clay content was progressively increased, the void shape became progressively more irregular to the point where 40 per cent clay resulted in the formation of joint planes. The circular voids produced at low clay contents may be considered to be the result of entrapped air. On the other hand, the changing character of voids with increasing clay content reflects the increasing severity of plasmic shrinkage upon drying.

c. <u>Experiment 3</u> - this experiment was a composite of the first two experiments in that clay was added to both sand alone and to mixtures of sand and silt. The saturating medium was 0.5 N $FeCl_2$ rather than distilled water.

Results obtained were somewhat similar to those described for experiments 1 and 2, except that skeletal coatings were considerably smoother and much more continuous. Interskeletal braces were very common. It appeared that, upon drying, the iron completely infused the clay matrix and in that way strongly bonded the clays to the surface of the mineral grains in the form of coatings (Plate 11). As the amount of clay was increased there were corresponding increases in the size of both skeletal coatings and interskeletal braces. The fact that skeletal coatings, although somewhat thinner, were also present in sand plus silt mixtures indicated that silt had a decreased disruptive effect when some coating constituents were present in the form of true solutions.

Plate 11. Smooth, continuous Fe-clay skeleton coating produced with 0.5 N $FeCl_2 \cdot 4H_2O$ as the saturating media. Partially crossed nicols. Magnification 50X.

Genesis of Microfabrics Pertinent to Soils Studied

Calcareous Chlamydomorphic and Calcareous Chlamydomorphic Agglomeratic Fabrics

Micromorphological observations have indicated that these two fabrics are closely inter-related in that both exhibit considerable amounts of free grain cutans; they differ only in the degree and completeness of plasmic orientation. In the soils studied, however, Chlamydomorphic fabrics are restricted to Btk horizons while Chlamydomorphic Agglomeratic fabrics are found in all Bmk and Aek horizons.

Kubiena (1938) states that coatings on skeletal grains are produced when all plasmic materials are present in the peptized state or in true solution. On desiccation, soil solutions (which may fill almost all soil pores after excessive moistening) retire to the angles of the interskeletal spaces and to the surfaces of the grains, forming only a thin coating on the latter. Constituents of the plasma suspended in soil solutions are moved with them. If such constituents are present in the form of larger flocculated complexes, they cannot spread out

over the skeletal surfaces. They form intergranular braces if they are cemented to the grain surfaces, and space deposits if no cementation takes place.

The results of experiments 1, 2, 3 and similar ones of Dr. R. J. St. Arnaud (personal communication) are in general agreement with Kubiena's theory, but indicate also that coatings may form without the condition of complete peptization or true solution. Genesis of Chlamydomorphic Agglomeratic and Chlamydomorphic fabrics is probably a consequence of interactions among generally low clay contents, relatively low dithionite extractable iron contents (Tables 5 and 7) and high skeleton contents. It is highly probable that "free" iron oxides can occur in soils as coatings around clay particles (Stephen, 1967). When iron content in a sandy soil is low, major portions of the clay would tend to flocculate into microaggregates which would occur as interskeletal braces (adhering to skeletal grains at specific locations) or space deposits. Illuviation of solution iron into such material would enhance the coatings around clay particles and would also produce complete coatings around skeletal grains. Subsequent dispersal of the microaggregates through saturation, followed by desiccation could result in the uniform contraction of the clay suspension around skeletal grains. Periodic, complete desiccation would stabilize such coatings through the development of a network of weakly crystalline iron oxides. When most of the plasma has become thus oriented, the fabric is then called Chlamydomorphic. If clay material is illuviated contemporaneously into such material, then the resultant could be an argillic horizon with Chlamydomorphic fabric. Concomitant with this would be an increase in meta pores.

Free grain cutans have, on occasion, been interpreted as being indicative of illuviation (Brewer and Sleeman, 1969; Bartelli and Odell, 1960). This study shows that they may also be the result of natural plasmic coalescence upon drying when silt content is relatively low, when silt plus clay percentage is insufficient to fill interskeletal spaces, and when "free" iron content is sufficient to bind the plasmic mass to the skeletal grains.

Calcareous Rendzina Moder and Calcareous Mull-like Rendzina Moder Fabric

Moder and Mull-like moder fabrics occur contiguously in surface, humified horizons. They are characterized by relatively high contents of organic fragments and organic matter, and higher silt contents but lower sand contents than that contained in "paleo" B horizons. These fabrics exhibit large amounts of cryptocrystalline, secondary carbonate precipitates which tend to flocculate and bind the plasma into loose, oblate aggregates (Tables 5 and 7).

Development of these fabrics is primarily a function of faunal activity and surface accretion. Micromorphological observations indicate a considerable incidence of excrement granules and fragmented, chewed, organic fragments. This points to the presence, in Ahk horizons, of considerable numbers of soil fauna, many of which would belong to the family Arthropoda. The action of soil arthropods would result in comminution of surface litter, rendering it more susceptible to the corrosiveness of alkaline soil reaction and bacterial decomposition. Coincident to this, is the slow accretion of calcareous, aeolian material to the surface of these soils, together with some intermixing of organic and mineral constituents by the arthropods. The resultant would be moder and mull-like moder fabrics in an Ahk horizon that

would thicken progressively towards the source of the aeolian material.

Genesis of the Soils

Results of field and laboratory studies indicate these soils to have had a polygenetic origin. The presence of a "paleo" B which becomes buried progressively deeper as the source of the aeolian material is approached, points to its formation during some period in the past. At the same time, recent pedogenesis may be of significance in that internal clay translocation has occurred in regions where burial has been about 10 inches or less. In addition, the presence of humified, surficial horizons whose physical make-up differs from that of the "paleo" B horizon suggests a hiatus in deposition of sufficient time to allow for the formation of the "paleo" B horizon. Confounding the entire situation is the fact that translocation of both clay and iron has occurred in a material in which free lime is present.

An examination of the available geochronology (Fig. 12) provides little insight into the problem. The "paleo" B horizon, as indicated, could have been in existence for about the past 2500 years. The bottom charcoal bed in the Ahk material dates about 2200 years, indicating that if a hiatus occurred, it was of relatively short duration. In fact, a change in wind velocity and/or a change in the nature of sediment load carried by the Athabasca River would be sufficient to explain the observed differences in lithologies in these materials. At the same time, however, the abrupt change in character between the "paleo" B and the Ahk material, and the fact that the "paleo" B is buried at continually varying depths make either of the above explanations implausible. As a consequence, the occurrence of a hiatus must be assumed.

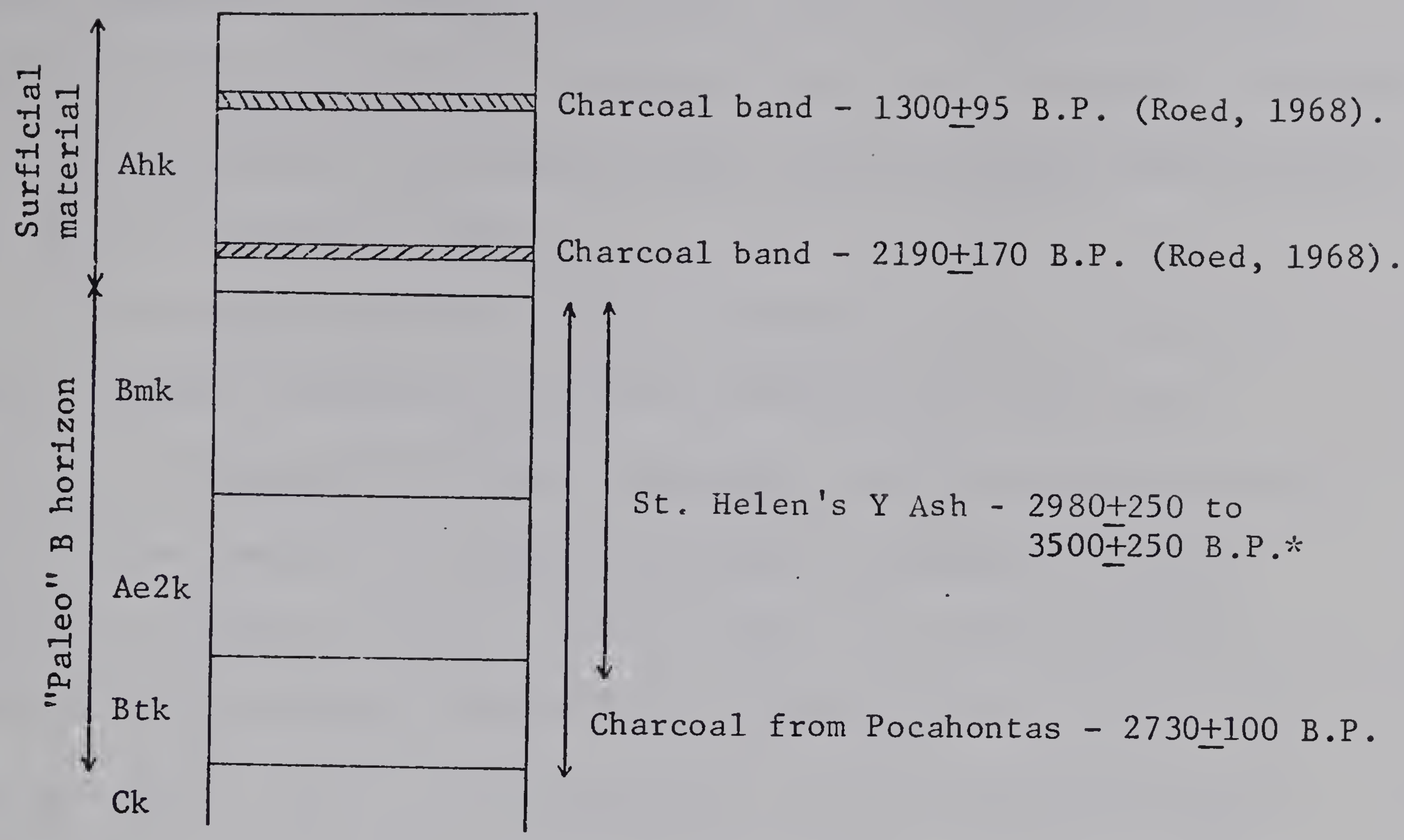

Fig. 12. Inferred geochronology of a composite section.

On the basis of this assumption, the following sequence of events could be postulated:

1) Deposition of calcareous, aeolian material following the withdrawal of the Obed glacier.

2) Colonization of this material by plants. This would result in the release of iron present in the primary carbonates, the dissemination of which would form the "paleo" B horizon. The fact that no internal transformations within the "paleo" B are evident in regions where this horizon is buried to excessive depths indicates that the environment did not at any time become excessively acid. These soils would be equivalent to Eutric Brunisols (Cryochrepts), and genesis of such soils correlates with a relatively short hiatus in deposition. Part of the color of this horizon may be directly related to age (Price, 1962).

3) Subsequent resumption of loessial deposition, coupled with

* This ash is reworked. Therefore age is younger than is indicated.

litter comminution by various soil fauna, began the formation of Ahk material in which there were considerable quantities of primary carbonates. In western portions of the region, rapid, excessive burial then preserved the "paleo" B horizon in place.

4) In regions where the "paleo" B remained within the zone of active pedogenic weathering, internal transformations took place. Initially, weathering of primary carbonates in the Ahk material resulted in the dissemination of secondary carbonates throughout the solum. Laboratory analysis, however, indicated that the highest secondary carbonate accumulations occurred within the Ahk and Ck horizons, with contents in the "paleo" B being quite low. Also, micromorphological observations revealed that secondary carbonates were not disseminated uniformly throughout the "paleo" B horizon, but were concentrated in discrete, local areas. Such an arrangement permitted the physical translocation of clays and associated iron from the upper portions to the lower portions of the "paleo" B horizon, ultimately resulting in the development of Btk horizons with Chlamydomorphic fabric. Such horizons are somewhat analogous to the beta B horizons of Bartelli and Odell (1960).

Contemporaneously, the weathering of primary carbonates released certain amounts of iron. Thin sections revealed the presence of siderite in Ahk and Ck horizons, but not within the "paleo" B. Initially, the iron precipitated within the Ahk horizon mostly in the form of iron carbonates and iron humates. Subsequent solution - precipitation cycles resulted in the progressive movement of iron to the lower parts of the Ahk and even into the upper portions of the "paleo" B. The drastic decrease in secondary carbonates within these latter regions then

promoted iron precipitation as oxides, with ultimate stabilization on clay surfaces. The resultant of this process was the development of Bmk horizons with Chlamydomorphic Agglomeratic fabric. Reactions typical of this sequence may be as follows (Bear, 1955):

$$Fe^{2+} + CaCO_3 \leftrightarrows FeCO_3 + Ca^{2+}$$

$$4FeCO_3 + O_2 + Ca(HCO_3)_2 \leftrightarrows 2Fe_2(CO_3)_3 + Ca(OH)_2$$

$$Fe_2(CO_3)_3 + 3H_2O \leftrightarrows Fe_2O_3 + 3H_2CO_3$$

The growth of the Bmk horizon is promoted by the constant accretion of loessial material to the top of the profile, the resultant of which is the development of an Ahk horizon with Moder and Mull-like Moder fabrics.

It should be realized that all the above processes pertain to only Calcareous Brunisolic Moder Gray Brown Luvisols. Soils with other morphologies and microfabrics would develop through the application of only pertinent portions of the total process, e.g. Calcareous Brunisolic Gray Luvisols would not experience appreciable accumulation of Ahk material.

SUMMARY AND CONCLUSIONS

This study has traced the development of the calcareous soils present in the Hinton area of Alberta. These soils have developed on aeolian material, the deposition of which continues today, and therefore they exhibit the geographic distribution of properties common to loess-derived soils (Ruhe, 1969; Rieger and Juve, 1961). The concave nature of the Athabasca River valley, the region in which these soils are found, dictates a vertical soil distribution pattern similar in all respects to the geographic pattern of distribution.

These soils were studied from the aspects of distribution, characterization and classification, as well as genesis. A detailed micromorpho-

logical approach was used to determine the genesis. Micromorphological observations were quantified by use of the point count procedure, and by chemical and physical means. Statistical analysis of the results facilitated detailed observations on fabric genesis, from which it was possible to make interpretations in terms of the development of individual soil horizons.

Results of the study found that both the soils and their associated microfabrics were unique. Clay and iron translocation had occurred in spite of the presence of free lime carbonates throughout the solum. Thin sections revealed that although secondary carbonates had completely disseminated the plasma of both Ahk and Ck horizons, their presence in the "paleo" B horizon was restricted to discrete, local areas, commonly associated with former root channels. This lead to the development of a hypothesis on the genesis of these soils, based on considerations of the geochronology of the aeolian material.

Excessive amounts of lime carbonates in a soil can pose peculiar problems in terms of soil management, since the activity of $CaCO_3$ may, on occasion, disturb the nutrient balance. In general, pH in calcareous soils is a function of the partial pressure of CO_2 and the proportion of water in the soil. Since the partial CO_2 pressure in a soil is usually several hundred times greater than that of the atmosphere, the movement, as hydrolysis occurs, is toward the bicarbonate form (Buckman and Brady, 1960):

$$CaCO_3 + H_2O \leftrightharpoons Ca^{2+} + HCO_3^- + OH^-$$

As pH increases beyond about pH 5.5, activities of iron and aluminum decrease, and phosphate is adsorbed onto clay surfaces, making it less available to plants. With further increases in pH, phosphate

solubility gradually becomes controlled by reactions with calcium in which case it becomes adsorbed on surfaces of calcite crystals and precipitates as tricalcium phosphates, fluorapatite or hydroxyapatite. Such forms are unavailable to plants. In addition to reactions with phosphates, excess lime may induce deficiencies in iron, manganese, copper, zinc and boron. Lime induced iron chlorosis is a common malady on many high lime soils as is lime induced potassium fixation (Buckman and Brady, 1960).

It is conceivable that plant growth and nutrition could be helped by acidification of alkaline-calcareous soils. However, a soil containing even moderate quantities of free lime has such a high buffering capacity, that treatments with impractically large amounts of chemicals would be necessary to completely remove the lime. The economics of such procedures are beyond the scope of this report. At the same time, the evidence is not conclusive that treatments insufficient to react with all of the excess lime significantly increase plant nutrient uptake and crop yield (Bear, 1955).

Calcareous, loess-derived soils are highly susceptible to erosion when disturbances have left them unprotected. This property is a direct reflection of the micromorphological arrangement of constituents. Chlamydomorphic Agglomeratic fabric, which occurs within the greatest portion of the "paleo" B horizon, is characterized by the presence of weakly aggregated, oblate granules which loosely occupy interskeletal spaces. Since binding between grains is very weak, such materials could easily be moved by either wind or water. Also, Kubiena (1938) believes that soils subject to continual crystal growth remain in a loose, friable state due to disruption by crystal efflorescence.

Visual appraisals in the Hinton area indicate that these soils are suitable for the growth of grasses and legumes, and respond well to nitrogenous fertilizers. They are problem soils, however, when used for forest production. Cox, McConnell and Mathews (1960) report a substantial decrease in site index for Ponderosa Pine for soils which contain residual calcium carbonate near the surface.

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APPENDIX

Profile Descriptions

Profile no: Htn 11
Classification: Calcareous Brunisolic Moder Gray Brown Luvisol
Topography: Generally class e-f slopes
Position: Hillcrest
Native Cover: Disturbed deciduous & evergreen
Drainage: Good
Location: NW 24-50-26-5

Ahk: 0-17"; sandy loam[1]; very dark grayish brown (10YR 3/2)[2]; poorly developed, fine granular; moist friable; abrupt boundary grading to

Bmk: 17-25"; sandy loam; yellowish red (5YR 4/6); poorly developed, fine subangular blocky to granular; moist friable; clear boundary grading to

Ae2k: 25-29"; loamy sand; strong brown (7.5YR 5/6); poorly developed, coarse plady to fine granular; moist friable; abrupt boundary to

Btk: 29-35"; sandy loam; dark brown (7.5YR 4/4); poorly developed, fine subangular blocky to fine granular; moist friable, but hard when dry; abrupt boundary to

Ck: 35-48"; sandy loam; olive brown (2.5Y 4/4); poorly developed, fine granular to massive; moist friable, abrupt boundary to

IICk: 48" +; Obed till; not sampled.

Table Al.1 Chemical Analysis

Lab. No.	Hor.	pH	%N[3]	%O.C.[4]	C/N	$\%CaCO_3$ Equiv.	Oxalate %Fe	Oxalate %Al	Dithionite %Fe	Dithionite %Al
R66412	Ahk	7.5	0.20	4.17	21	16.85	0.16	0.04	0.82	0.30
413	Bmk	7.7	0.05	0.28	6	1.62	0.15	0.24	1.26	0.50
414	Ae2k	8.0	0.03	0.22	8	0.67	0.04	0.02	0.83	0.39
415	Btk	7.8	0.04	0.26	7	0.89	0.04	0.02	1.06	0.42
416	Ck	7.9	-	-	-	9.90	0.04	0.01	0.70	0.28

1. Field textures. Similar in all succeeding descriptions.
2. Munsell color notation. All colors are moist unless otherwise stated.
3. Per cent total nitrogen.
4. Per cent organic carbon.

Table A1.2 Particle Size Analysis

Horizon	% Sand	% Silt	% Total* Clay	% Fine** Clay
Ahk	12	72	16	8
Bmk	30	52	18	6
Ae2k	51	37	12	5
Btk	59	25	16	9
Ck	47	43	10	4

Profile no: Htn 13 Monolith
Classification: Calcareous Brunisolic Gray Luvisol
Topography: Class d-e
Position: Midslope
Native Cover: White spruce, aspen, buffalo berry, feather mosses, grasses
Drainage: Good
Location: SW 14-52-24-5

L-Hk: 2-0"; fibric with many roots.

Bmk: 0-6"; fine sandy loam; dark brown (7.5YR 4/4) moist, yellowish brown (10YR 5/6) dry; poorly developed, fine subangular blocky; moist friable; clear boundary to

Ae2k: 6-13"; sandy loam; light yellowish brown (10YR 6/4) moist; pale brown (10YR 6/3) dry; poorly developed, fine subangular blocky; moist friable; clear boundary to

Btk: 13-20"; sandy clay loam; dark yellowish brown (10YR 4/4) moist; pale brown (10YR 6/3) dry; poorly developed, coarse subangular blocky; moist friable; abrupt boundary to

Ck: 20-48"; sandy loam (heavy); grayish brown (2.5Y 5/2) moist; white (10YR 8/1) dry; single grain; abrupt boundary to

IICk: 48" +; Obed till; not sampled.

Table A2.1 Chemical Analysis

Lab. No.	Hor.	pH	%N	%O.C.	C/N	$\%CaCO_3$ Equiv.	Oxalate %Fe	Oxalate %Al	Dithionite %Fe	Dithionite %Al
R67124	L-Hk	7.8	-	-	-	11.74	0.06	0.02	0.69	0.00
125	Bmk	7.7	0.06	0.86	14	0.20	0.07	0.02	1.06	0.00
126	Ae2k	8.0	0.02	0.03	15	0.56	0.04	0.02	0.70	0.02
127	Btk	7.9	0.03	0.31	10	0.48	0.05	0.03	0.95	0.05
128	Ck	8.3	-	-	-	16.38	0.03	0.01	0.41	0.02

* $< 2.0\ \mu$ - similar in all succeeding descriptions.
** $< 0.2\ \mu$ - similar in all succeeding descriptions.

Table A2.2 Particle Size Analysis

Horizon	% Sand	% Silt	% Total Clay	% Fine Clay
L-Hk	-	-	-	-
Bmk	54	35	11	7
Ae2k	63	31	6	3
Btk	60	31	9	8
Ck	68	29	3	3

Profile no: Htn 15
Classification: Calcareous Brunisolic Moder Gray Brown Luvisol
Topography: Class e
Position: Midslope
Native Cover: Aspen, white spruce, buffalo berry
Drainage: Good
Location: SE 11-51-26-5

Ahk: 0-9"; very fine sandy loam; very dark grayish brown (10YR 3/2); poorly developed, fine granular to single grain; moist friable; abrupt boundary to

Bmk: 9-14"; very fine sandy loam (heavy); brown (7.5YR 5/4); poorly developed, fine platy; moist friable; clear boundary to

Ae2k: 14-18"; fine sandy loam (heavy); yellowish brown (10YR 5/6); poorly developed, fine platy; moist friable; clear boundary to

Btk: 18-22"; fine sandy clay loam (heavy); yellowish brown (10YR 5/4); poorly developed, medium subangular blocky; moist friable; abrupt boundary to

Ck: 22-26"; fine sandy clay loam; grayish brown (2.5Y 5/2); single grain; moist friable; abrupt boundary to

IICk: 26" +; very cobbly gravels; not sampled.

Table A3.1 Chemical Analysis

Lab. No.	Hor.	pH	%N	%O.C.	C/N	%CaCO3 Equiv.	Oxalate %Fe	Oxalate %Al	Dithionite %Fe	Dithionite %Al
R67175	Ahk	7.7	0.27	3.66	14	24.45	0.17	0.05	0.78	0.20
176	Bmk	8.0	0.03	0.21	7	1.49	0.06	0.01	0.66	0.08
177	Ae2k	7.9	0.02	0.10	5	0.72	0.04	0.00	0.91	0.08
178	Btk	7.8	0.03	0.19	6	0.38	0.06	0.02	0.96	0.09
179	Ck	7.9	-	-	-	8.37	0.08	0.02	0.88	0.12

Table A3.2 Particle Size Analysis

Horizon	% Sand	% Silt	% Total Clay	% Fine Clay
Ahk	19	71	10	3
Bmk	58	38	4	4
Ae2k	57	36	7	4
Btk	53	35	12	9
Ck	39	51	10	6

Profile no: Htn 21 Monolith
Classification: Calcareous Brunisolic Moder Gray Brown Luvisol
Topography: Class f
Position: Midslope
Native Cover: Aspen, white spruce, buffalo berry
Drainage: Good
Location: 9-51-26-5

Ahk: 0-6"; silt loam; dark gray (10YR 4/1) dry; poorly developed, fine granular to single grain; moist friable; few vesicles; gradual boundary to

Ahek: 6-11"; silt loam; dark grayish brown (10YR 4/2) dry; poorly developed, fine granular to single grain; moist friable; moderate vesicle content; abrupt boundary to

Bmk: 11-16"; fine sandy loam; reddish yellow (7.5YR 6/6) dry; moderately developed, medium subangular blocky to single grain; moist friable; moderate vesicle content; clear boundary to

Ae2k: 16-21"; fine sandy loam; light rellowish brown (10YR 6/4) dry; poorly developed, coarse subangular blocky to single grain; moist friable; few vesicles; clear boundary to

Btk: 21-28"; fine sandy clay loam; yellowish brown (10YR 5/6) dry; poorly developed, medium to fine prismatic to subangular blocky; moist friable, dry hard; many vesicles; abrupt, irregular, glossic boundary to

Ck: 28-54"; sandy loam (heavy); grayish brown (10YR 5/2) dry; single grain; moist friable; many vesicles.

Table A4.1 Chemical Analysis

Lab. No.	Hor.	pH	%N	%O.C.	C/N	$\%CaCO_3$ Equiv.	Oxalate %Fe	Oxalate %Al	Dithionite %Fe	Dithionite %Al
R68534	Ahk	7.5	0.43	7.92	18	20.49	0.42	0.06	0.88	0.18
535	Ahek	7.9	0.24	3.57	15	14.09	0.70	0.19	0.86	0.04
536	Bmk	8.1	0.02	0.11	6	1.18	0.14	0.06	0.65	0.02
537	Ae2k	8.0	0.02	0.04	2	0.81	0.11	0.03	0.75	0.02
538	Btk	7.8	0.05	0.34	7	1.47	0.19	0.11	0.93	0.03
539	Ck	8.1	-	-	-	18.86	0.11	0.05	0.65	0.02

Table A4.2 Particle Size Analysis

Horizon	% Sand	% Silt	% Total Clay	% Fine Clay
Ahk	27	65	8	5
Ahek	32	56	12	4
Bmk	71	27	2	2
Ae2k	70	24	6	2
Btk	53	28	19	10
Ck	63	31	6	4

Profile no: Htn 26 Monolith
Classification: Calcareous Orthic Moder Melanic Brunisol
Topography: Class d
Position: Hillcrest
Native Cover: Aspen, white spruce, buffalo berry, grasses, vaccinium
Drainage: Good
Location: SW 4-51-25-5

Ah1k: 0-2 1/2"; loam; very dark gray (10YR 3/1) dry; moderately developed, fine granular; moist friable; gradual boundary to

Ah2k: 2 1/2-5"; sandy loam; brown (10YR 5/3) dry; poorly developed, medium subangular blocky to granular; moist friable; abrupt boundary to

Bmk: 5-10"; loamy sand; yellowish brown (10YR 5/6) dry; poorly developed, coarse subangular blocky to single grain; moist friable; clear boundary to

Ck: 10-13"; loamy sand; grayish brown (10YR 5/2) dry; single grain; moist friable.

Table A5.1 Chemical Analysis

Lab. No.	Hor.	pH	%N	%O.C.	C/N	$\%CaCO_3$ Equiv.	Oxalate %Fe	Oxalate %Al	Dithionite %Fe	Dithionite %Al
R68610	Ah1k	8.2	0.26	4.00	15	12.58	0.83	0.19	0.86	0.04
611	Ah2k	8.3	0.12	1.52	13	5.60	0.84	0.19	0.68	0.02
612	Bmk	8.3	0.04	0.37	9	3.84	0.42	0.27	0.52	0.03
614	Ck	8.4	-	-	-	19.02	0.32	0.14	0.36	0.01

Table A5.2 Particle Size Analysis

Horizon	% Sand	% Silt	% Total Clay	% Fine Clay
Ah1k	43	42	15	6
Ah2k	55	29	16	6
Bmk	88	6	6	4
Ck	85	12	3	2

Profile no: Htn 27 Monolith
Classification: Calcareous Degraded Moder Melanic Brunisol
Topography: Class d
Position: Lower slope
Native Cover: Aspen, white spruce, buffalo berry, vaccinium, grasses
Drainage: Good
Location: SW 4-51-25-5

Ahk: 0-3 1/2"; loam; black (10YR 2/1) dry; poorly developed, fine granular to single grain; moist friable; abrupt boundary to

Aek: 3 1/2-8"; silt loam; brown (10YR 5/3) dry; poorly developed, medium subangular blocky to single grain; moist friable; clear boundary to

Bmk: 8-15 1/2"; sandy loam; yellowish brown (10YR 5/5) dry; moderately developed, medium subangular blocky to single grain; moist friable; dry slightly hard; gradual boundary to

BCk: 15 1/2-23"; sandy loam; light olive brown (2.5Y 5/5) dry; poorly developed, coarse subangular blocky to single grain; moist friable; dry soft; clear boundary to

Ck: 23-27"; loamy sand; grayish brown (2.5Y 5/2) dry; single grain; moist friable; dry soft.

Table A6.1 Chemical Analysis

Lab. No.	Hor.	pH	%N	%O.C.	C/N	$\%CaCO_3$ Equiv.	Oxalate %Fe	Oxalate %Al	Dithionite %Fe	Dithionite %Al
R68615	Ahk	7.9	0.43	8.19	25	10.81	0.59	0.13	0.76	0.09
616	Aek	8.2	0.25	3.56	14	9.16	0.92	0.37	1.08	0.07
617	Bmk	8.0	0.04	0.43	12	0.71	0.35	0.18	0.60	0.02
619	BCk	8.0	0.02	0.24	9	0.58	0.34	0.36	0.64	0.04
621	Ck	8.2	-	-	-	12.47	0.10	0.06	0.36	0.04

Table A6.2 Particle Size Analysis

Horizon	% Sand	% Silt	% Total Clay	% Fine Clay
Ahk	44	45	11	4
Aek	24	70	6	4
Bmk	60	33	7	5
BCk	67	24	9	7
Ck	80	12	8	4

Profile no: Htn 28
Classification: Calcareous Degraded Moder Melanic Brunisol
Topography: Class e-f
Position: Midslope
Native Cover: White spruce
Drainage: Good
Location: SW 29-50-26-5

Ahk: 0-8"; silt loam; very dark grayish brown (10YR 3/2) poorly developed, fine granular; moist friable; clear boundary to

Aek: 8-13"; sandy loam; yellowish brown (10YR 5/6); poorly developed, fine granular to single grain; moist friable; clear boundary to

Bmk: 13-17"; sandy loam; yellowish red (5YR 4/8); poorly developed, medium to fine subangular blocky to single grain; moist friable; gradual boundary to

BCk: 17-25"; sandy loam; yellowish brown (10YR 5/4); poorly developed, fine subangular blocky to single grain, moist friable; abrupt boundary to

IICk: 25" +; Obed till; not sampled.

Table A7.1 Chemical Analysis

Lab. No.	Hor.	pH	%N	%O.C.	C/N	$\%CaCO_3$ Equiv.	Oxalate %Fe	Oxalate %Al	Dithionite %Fe	Dithionite %Al
R69153	Ahk	8.3	0.23	3.40	15	26.17	0.55	0.09	0.84	0.08
154	Aek	8.2	0.01	0.07	7	0.71	0.13	0.02	0.46	0.03
155	Bmk	8.1	0.01	0.03	3	0.55	0.13	0.01	0.46	0.02
156	BCk	7.8	-	-	-	0.33	0.13	0.02	0.41	0.02

Table A7.2 Particle Size Analysis

Horizon	% Sand	% Silt	% Total Clay	% Fine Clay
Ahk	20	79	1	0
Aek	87	11	1	1
Bmk	91	6	3	1
BCk	91	6	3	1

Profile no: Htn 29
Classification: Calcareous Orthic Moder Melanic Brunisol
Topography: Class d-e
Position: Upper slope
Native Cover: White spruce, aspen, buffalo berry
Drainage: Good
Location: SE 32-50-25-5

L-Hk: 3-0"; Partially decomposed leaves and needles

Ahk: 0-3"; silt loam; very dark grayish brown (10YR 3/2); poorly developed, fine granular to single grain; moist friable; abrupt boundary to

Bmk: 3-9"; silt loam; brown (7.5YR 4/4); poorly developed, fine subangular blocky to single grain; moist friable; clear boundary to

BCk: 9-15"; fine sandy clay loam; yellowish brown (10YR 5/6); poorly developed, fine subangular blocky to single grain; moist friable; clear boundary to

Ck: 15-22"; fine sandy clay loam; yellowish brown (10YR 5/4); massive to single grain; moist friable; abrupt boundary to

IICk: 22" +; Obed till; not sampled.

Table A8.1 Chemical Analysis

Lab. No.	Hor.	pH	%N	%O.C.	C/N	%$CaCO_3$ Equiv.	Oxalate %Fe	Oxalate %Al	Dithionite %Fe	Dithionite %Al
R69157	L-Hk	7.6	-	-	-	8.48	0.30	0.08	0.40	0.05
158	Ahk	8.1	0.06	2.14	36	17.82	0.77	0.18	1.12	0.02
159	Bmk	8.0	0.10	0.93	9	3.89	0.47	0.15	0.88	0.09
160	BCk	7.6	-	-		0.73	0.20	0.09	0.94	0.08
161	Ck	7.6	-	-		0.76	0.20	0.05	0.75	0.06

Table A8.2 Particle Size Analysis

Horizon	% Sand	% Silt	% Total Clay	% Fine Clay
L-Hk	-	-	-	-
Ahk	11	71	18	4
Bmk	25	64	11	6
BCk	50	35	15	10
Ck	57	36	9	5

Profile no: Htn 30
Classification: Calcareous Orthic Moder Melanic Brunisol
Topography: Class d
Position: Midslope
Native Cover: White spruce, buffalo berry
Drainage: Good
Location: SW 8-50-26-5

Ah1k: 0-6"; silt loam; very dark grayish brown (10YR 3/2); poorly developed, fine granular to single grain; moist friable; gradual boundary to

Ah2k: 6-12"; silt loam; dark grayish brown (10YR 4/2); poorly developed, fine granular to single grain; moist friable; gradual boundary to

Ah3k: 12-14"; very fine sandy loam; dark brown (10YR 3/3); poorly developed, fine subangular blocky to single grain; moist friable; abrupt boundary to

Bmk: 14-20"; sandy loam; strong brown (7.5YR 5/6); poorly developed, fine subangular blocky to single grain; moist friable; clear boundary to

BCk: 20-24"; sandy loam; yellowish brown (10YR 5/6); poorly developed, fine subangular blocky to single grain; moist friable; clear boundary to

Ck: 24" +; sandy loam; yellowish brown (10YR 5/4); single grain; moist friable.

Table A9.1 Chemical Analysis

Lab. No.	Hor.	pH	%N	%O.C.	C/N	%$CaCO_3$ Equiv.	Oxalate %Fe	Oxalate %Al	Dithionite %Fe	Dithionite %Al
R69143	Ah1k	8.2	0.24	2.91	12	34.08	0.47	0.05	0.72	0.06
144	Ah2k	8.2	0.16	2.48	16	37.88	0.77	0.10	0.69	0.08
145	Ah3k	8.4	0.08	0.81	10	5.59	0.50	0.18	0.76	0.06
146	Bmk	8.3	0.01	0.07	7	0.60	0.20	0.04	0.50	0.04
147	BCk	8.4	-	-	-	2.30	0.20	0.04	0.62	0.06
148	Ck	8.3	-	-	-	14.32	0.20	0.03	0.34	0.04

Table A9.2 Particle Size Analysis

Horizon	% Sand	% Silt	% Total Clay	% Fine Clay
Ah1k	27	66	7	3
Ah2k	20	74	6	2
Ah3k	55	39	6	2
Bmk	82	16	2	1
BCk	81	15	4	3
Ck	86	9	5	2

Profile no: Htn 31
Classification: Calcareous Cumulic Regosol
Topography: Class d
Position: Hillcrest
Native Cover: White spruce, feather mosses
Drainage: Good
Location: SW 19-50-26-5

Ah1k: 0-6"; loam; very dark gray (10YR 3/1); poorly developed, fine granular to single grain; moist friable; gradual boundary to

Ah2k: 6-12"; very fine sandy loam; very dark grayish brown (10YR 3/2); poorly developed, fine granular to single grain; moist friable; gradual boundary to

Ah3k: 12-20"; similar to Ah2k except for slight red colors

Ah4k: 20-23"; silt loam; dark brown (7.5YR 3/2); poorly developed, fine granular to single grain; moist friable; abrupt boundary to

IIBmk: 23-28"; Obed till; not sampled.

IICk: 28" +; Obed till; not sampled.

Table A10.1 Chemical Analysis

Lab. No.	Hor.	pH	%N	%O.C.	C/N	$\%CaCO_3$ Equiv.	Oxalate %Fe	Oxalate %Al	Dithionite %Fe	Dithionite %Al
R69149	Ah1k	8.2	0.37	5.41	15	27.39	0.30	0.02	0.61	0.04
150	Ah2k	8.3	0.17	3.44	20	25.59	0.64	0.08	0.77	0.08
151	Ah3k	8.2	0.21	4.28	20	26.12	0.39	0.06	0.67	0.06
152	Ah4k	8.3	0.15	1.27	8	34.42	0.55	0.11	0.98	0.08

Table A10.2 Particle Size Analysis

Horizon	% Sand	% Silt	% Total Clay	% Fine Clay
Ah1k	34	59	7	2
Ah2k	32	61	7	2
Ah3k	23	75	2	2
Ah4k	17	75	8	4

Profile no: Htn 40
Classification: Calcareous Orthic Eutric Brunisol
Topography: Class d
Position: Hillcrest
Native Cover: Aspen, white spruce, vaccinium
Drainage: Good
Location: SW 32-51-24-5

L-Hk: 1-0"; Partially decomposed plant remains

Ahk: 0-1"; silt loam; black (5YR 2/1); poorly developed, fine granular to single grain; moist friable; abrupt boundary to

Bmk: 1-7"; loam; reddish brown (5YR 4/4); poorly developed, fine to medium subangular blocky to single grain; moist friable; abrupt boundary to

IICk: 7" +; cobbley gravels; not sampled.

Table A11.1 Chemical Analysis

Lab. No.	Hor.	pH	%N	%O.C.	C/N	$\%CaCO_3$ Equiv.	Oxalate %Fe	Oxalate %Al	Dithionite %Fe	Dithionite %Al
R69287	Ahk	7.6	0.99	25.22	25	5.25	0.23	0.01	0.62	0.06
288	Bmk	7.7	0.10	2.11	21	1.31	0.50	0.14	1.00	0.10

Table A11.2 Particle Size Analysis

Horizon	% Sand	% Silt	% Total Clay	% Fine Clay
Ahk	9	77	14	6
Bmk	27	57	16	5

Profile no: Htn 41
Classification: Calcareous Degraded Eutric Brunisol
Topography: Class b-c
Position -
Native Cover: White spruce, aspen, feathermoss
Drainage: Good
Location: NW 30-51-24-5

L-Hk: 1-0"; Partially decomposed plant remains

Ahk: 0-1"; silt loam; black (10YR 2/1); poorly developed, granular to single grain; moist friable; abrupt boundary to

Aejk: 1-3"; silt loam; dark brown (7.5YR 5/2); poorly developed, fine subangular blocky to single grain; moist friable; clear boundary to

Bmk 3-8"; loam (heavy); reddish brown (5YR 4/4); poorly developed, fine subangular blocky to single grain; moist friable; abrupt boundary to

IICk: 8" +; cobbley gravels; not sampled.

Table A12.1 Chemical Analysis

Lab. No.	Hor.	pH	%N	%O.C.	C/N	$\%CaCO_3$ Equiv.	Oxalate %Fe	Oxalate %Al	Dithionite %Fe	Dithionite %Al
R69289	Ahk	7.4	0.67	15.83	24	3.66	0.47	0.13	0.94	0.11
290	Aejk	7.6	0.12	2.20	18	0.34	0.68	0.14	1.11	0.10
291	Bmk	7.6	0.07	1.04	15	0.31	0.55	0.21	1.00	0.08

Table A12.2 Particle Size Analysis

Horizon	% Sand	% Silt	% Total Clay	% Fine Clay
Ahk	14	64	22	6
Aejk	16	65	19	7
Bmk	30	53	17	7

Profile no: Htn 42
Classification: Calcareous Degraded Eutric Brunisol
Topography: Class d
Position: Upper slope
Native Cover: White spruce, aspen, pine, vaccinium
Drainage: Good
Location: SW 9-52-24-5

L-Hk: 1-0"; Partially decomposed grasses, needles, etc.

Ahk: 0-1"; silt loam; black (5YR 2/1); poorly developed, fine granular to single grain; moist friable; abrupt boundary to

Aek: 1-5"; silt loam; dark brown (7.5YR 4/4); poorly developed, fine subangular blocky to single grain; moist friable; clear boundary to

Bmk: 5-10"; silt loam; yellowish red (5YR 4/6); poorly developed, fine to medium subangular blocky; moist friable; abrupt boundary to

IICk: 10" +; cobbley gravel; not sampled.

Table A13.1 Chemical Analysis

Lab. No.	Hor.	pH	%N	%O.C.	C/N	$\%CaCO_3$ Equiv.	Oxalate %Fe	Oxalate %Al	Dithionite %Fe	Dithionite %Al
R69292	Ahk	7.4	0.77	16.78	22	0.46	0.47	0.12	0.95	0.10
293	Aek	7.7	0.13	2.45	19	0.33	0.50	0.13	1.11	0.10
294	Bmk	7.8	0.05	0.68	4	0.42	0.30	0.14	0.95	0.10

Table A13.2 Particle Size Analysis

Horizon	% Sand	% Silt	% Total Clay	% Fine Clay
Ahk	14	70	16	6
Aek	18	63	19	8
Bmk	39	46	15	8

Profile no: Htn 43
Classification: Calcareous Orthic Eutric Brunisol
Topography: Class b
Position: -
Native Cover: Lodgepole pine, aspen, buffalo berry
Drainage: Good
Location: NW 31-51-24-5

L-Hk: 2-0"; Partially decomposed plant remains

Ahk: 0-1"; silt loam; black (5YR 2/1); poorly developed, fine granular to single grain; moist friable; abrupt boundary to

Bmk: 1-8"; silt loam; brown (7.5YR 4.5/4); poorly developed, fine subangular blocky to single grain; moist friable; abrupt boundary to

IICk: 8" +; cobbley gravel; not sampled.

Table A14.1 Chemical Analysis

Lab. No.	Hor.	pH	%N	%O.C.	C/N	$\%CaCO_3$ Equiv.	Oxalate %Fe	Oxalate %Al	Dithionite %Fe	Dithionite %Al
R69295	Ahk	7.4	0.27	12.20	45	0.59	0.50	0.14	1.04	0.11
296	Bmk	7.7	0.14	2.48	18	0.34	0.82	0.24	1.18	0.11

Table A14.2 Particle Size Analysis

Horizon	% Sand	% Silt	% Total Clay	% Fine Clay
Ahk	10	81	9	5
Bmk	19	69	12	5

Profile no: Htn 44
Classification: Calcareous Degraded Eutric Brunisol
Topography: Class f-g
Position: Top of small plateau
Native Cover: Aspen, white spruce, lodgepole pine, vaccinium
Drainage: Good
Location: SW 26-51-25-5

L-Hk: 2-0"; Partially decomposed leaves, needles, etc.

Ahk: 0-1 1/2"; silt loam; dark brown (7.5YR 3/2); poorly developed, fine granular; moist friable; clear boundary to

Aek: 1 1/2-5"; silt loam; brown (7.5YR 5/4); poorly developed, fine subangular blocky to single grain; moist friable; clear boundary to

Bmk: 5-10"; loam; yellowish red (5YR 5/6); poorly developed, fine to medium subangular blocky to single grain; moist friable; abrupt boundary to

IICk: 10" +; Obed till; not sampled.

Table A15.1 Chemical Analysis

Lab. No.	Hor.	pH	%N	%O.C.	C/N	$\%CaCO_3$ Equiv.	Oxalate %Fe	Oxalate %Al	Dithionite %Fe	Dithionite %Al
R69297	Ahk	7.8	0.40	8.24	21	7.51	0.78	0.19	1.09	0.12
298	Aek	8.0	0.12	1.70	14	4.04	0.35	0.13	0.44	0.03
299	Bmk	8.0	0.02	0.44	22	0.60	0.10	0.04	0.63	0.03

Table A15.2 Particle Size Analysis

Horizon	% Sand	% Silt	% Total Clay	% Fine Clay
Ahk	20	64	16	7
Aek	29	60	11	5
Bmk	45	50	5	4

Profile no: Htn 45
Classification: Calcareous Degraded Eutric Brunisol
Topography: Class d
Position: Hillcrest
Native Cover: Aspen, white spruce, lodgepole pine, vaccinium
Drainage: Good
Location: NW 27-51-25-5

L-Hk: Partially decomposed plant remains

Ahk: 0-1/2"; loam; very dark grayish brown (10YR 3/2); poorly developed, fine granular; moist friable; clear boundary to

Aek: 1/2-7"; fine sandy loam; light brown (7.5YR 6/4); poorly developed, fine granular to single grain; moist friable; clear boundary to

Bmk 7-12"; loam; yellowish red (5YR 4/8); poorly to moderately developed, fine subangular blocky to single grain; moist friable; abrupt boundary to

IICk: 12" +; Obed till; not sampled.

Table A16.1 Chemical Analysis

Lab. No.	Hor.	pH	%N	%O.C.	C/N	$\%CaCO_3$ Equiv.	Oxalate %Fe	Oxalate %Al	Dithionite %Fe	Dithionite %Al
R69300	Aek	8.1	0.05	0.71	14	2.63	0.27	0.09	0.42	0.03
301	Bmk	8.0	0.04	0.42	11	1.10	0.10	0.08	1.26	0.10

Table A16.2 Particle Size Analysis

Horizon	% Sand	% Silt	% Total Clay	% Fine Clay
Aek	42	54	4	3
Bmk	45	36	19	13

Profile no: Htn 46
Classification: Calcareous Brunisolic Gray Luvisol
Topography: Class e
Position: Hillcrest
Native Cover: Aspen, lodgepole pine, white spruce, buffalo berry
Drainage: Good
Location: NE 29-50-25-5

L-Hk: 1-0"; Partially decomposed plant remains

Ahk: 0-1 1/2"; loam; dark reddish brown (5YR 2/2); poorly developed, fine granular to single grain; moist friable; clear boundary to

Bm1k: 1 1/2-6"; loam; dark reddish brown (5YR 3/2); poorly developed, fine subangular blocky to granular; moist friable; gradual boundary to

Bm2k: 6-10"; loam; yellowish red (5YR 4/6); poorly developed, fine subangular blocky to single grain; moist friable; clear boundary to

Ae2k: 10-14"; sandy loam; strong brown (7.5YR 5/6); poorly developed, fine to medium subangular blocky; moist friable; clear boundary to

Btk: 14-20"; very fine sandy loam (heavy); strong brown (7.5YR 5/6); poorly developed, medium subangular blocky to single grain; moist friable; dry slightly hard; clear boundary to

Ck: 20-24"; sandy loam; light gray (10YR 7/2); single grain; moist friable; abrupt boundary to

IICk: 24" +; Obed till; not sampled.

Table A17.1 Chemical Analysis

Lab. No.	Hor.	pH	%N	%O.C.	C/N	$\%CaCO_3$ Equiv.	Oxalate %Fe	Oxalate %Al	Dithionite %Fe	Dithionite %Al
R69302	Ahk	7.8	0.47	6.07	13	8.05	0.85	0.14	0.86	0.06
303	Bm1k	8.1	0.22	2.83	13	7.10	0.85	0.18	1.20	0.08
304	Bm2k	8.0	0.09	0.88	10	4.59	0.47	0.18	0.90	0.06
305	Ae2k	8.0	0.03	0.24	8	0.58	0.13	0.04	0.68	0.06
306	Btk	7.8	0.04	0.33	8	0.44	0.23	0.01	1.07	0.06
307	Ck	8.0	-	-	-	10.52	0.17	0.04	0.64	0.04

Table A17.2 Particle Size Analysis

Horizon	% Sand	% Silt	% Total Clay	% Fine Clay
Ahk	22	68	10	4
Bm1k	18	69	13	3
Bm2k	34	59	7	3
Ae2k	61	32	7	2
Btk	56	35	9	3
Ck	46	45	9	8

Profile no: Htn 47
Classification: Calcareous Degraded Moder Melanic Brunisol
Topography: Class c-d
Position: Hillcrest
Native Cover: White spruce, aspen, buffalo berry
Drainage: Good
Location: SE 12-51-26-5

L-Hk: 1-0"; Partially decomposed leaves, needles, etc.

Ahk: 0-4"; Silt loam; very dark brown (10YR 2/2); poorly developed, fine granular to single grain; moist friable; gradual boundary to

Aek: 4-8"; loam; brown (7.5YR 5/4); poorly developed, fine subangular blocky to single grain; moist friable; gradual boundary to

Bmk: 8-14"; sandy loam; yellowish red (5YR 4/7); poorly developed, fine to medium subangular blocky to single grain; moist friable; abrupt boundary to

IICk: 14" +; cobbley gravel; not sampled.

Table A18.1 Chemical Analysis

Lab. No.	Hor.	pH	%N	%O.C.	C/N	$\%CaCO_3$ Equiv.	Oxalate %Fe	Oxalate %Al	Dithionite %Fe	Dithionite %Al
R69308	Ahk	8.0	0.27	3.42	13	13.31	0.82	0.13	1.07	0.08
309	Aek	8.1	0.05	0.76	15	5.24	0.39	0.14	0.76	0.05
310	Bmk	8.1	0.03	0.17	6	0.40	0.20	0.06	0.69	0.06

Table A18.2 Particle Size Analysis

Horizon	% Sand	% Silt	% Total Clay	% Fine Clay
Ahk	23	65	12	3
Aek	48	41	11	4
Btk	63	31	6	3

Profile no: Htn 48
Classification: Calcareous Orthic Moder Melanic Brunisol
Topography: Class c-d
Position: Midslope
Native Cover: White spruce, aspen
Drainage: Good
Location: SW 17-51-25-5

Ahk: 0-6"; loam; black (5YR 2/1); poorly developed, fine granular to single grain; moist friable; gradual boundary to

Bmk: 6-12"; loam; yellowish red (5YR 5/6); poorly developed, fine subangular blocky to single grain; moist friable; gradual boundary to

BCk: 12-14"; not sampled.

IICk: 14" +; Obed till; not sampled.

Table A19.1 Chemical Analysis

Lab. No.	Hor.	pH	%N	%O.C.	C/N	$\%CaCO_3$ Equiv.	Oxalate %Fe	Oxalate %Al	Dithionite %Fe	Dithionite %Al
R69311	Ahk	7.8	0.47	8.03	17	24.50	0.30	0.09	0.64	0.14
312	Bmk	8.1	0.06	0.66	11	0.44	0.35	0.14	0.95	0.06

Table A19.2 Particle Size Analysis

Horizon	% Sand	% Silt	% Total Clay	% Fine Clay
Ahk	28	58	14	5
Bmk	48	41	11	5

Profile no: Htn 49
Classification: Calcareous Brunisolic Gray Luvisol
Topography: Class e
Position: Hillcrest
Native Cover: Aspen, white spruce, buffalo berry
Drainage: Good
Location: SE 24-51-25-5

L-Hk: 1-0"; Partially decomposed plant remains

Bmk: 0-2"; fine sandy loam; dark reddish yellow (5YR 3/4); poorly developed, fine subangular blocky to single grain; moist friable; clear boundary to

Ae2k: 2-11"; sandy loam; brown (7.5YR 5/4); poorly developed, fine subangular blocky to single grain; moist friable; clear boundary to

Btk: 11-18"; sandy clay loam; yellowish brown (10YR 5/5); poorly developed, fine to medium subangular blocky to single grain; moist friable; dry slightly hard; abrupt boundary to

Ck: 18-30"; loamy sand; grayish brown (10YR 5/2); single grain; moist friable; abrupt boundary to

IICk: 30" +; Obed till; not sampled.

Table A20.1 Chemical Analysis

Lab. No.	Hor.	pH	%N	%O.C.	C/N	$\%CaCO_3$ Equiv.	Oxalate %Fe	Oxalate %Al	Dithionite %Fe	Dithionite %Al
R69313	Bmk	7.9	0.10	1.61	16	0.35	0.68	0.18	0.82	0.07
314	Aek	7.9	0.03	0.34	11	0.60	0.23	0.05	0.64	0.05
315	Btk	7.9	0.03	0.24	8	0.80	0.20	0.08	0.84	0.09
316	Ck	8.1	-	-	-	16.09	0.10	0.01	0.31	0.04

Table A20.2 Particle Size Analysis

Horizon	% Sand	% Silt	% Total Clay	% Fine Clay
Bmk	41	46	13	4
Aek	68	22	10	4
Btk	67	19	14	9
Ck	87	10	3	1

Profile no: Htn 50
Classification: Calcareous Brunisolic Gray Luvisol
Topography: Class e-f
Position: Midslope
Native Cover: Aspen, white spruce, buffalo berry
Drainage: Good
Location: SW 29-51-24-5

L-Hk: 3-0"; Partially decomposed plant remains

Bmk: 0-4"; fine sandy loam (heavy); reddish brown (5YR 4/4); poorly developed, fine subangular blocky to single grain; moist friable; gradual boundary to

Ae2k: 4-7"; sandy loam; yellowish brown (10YR 5/6); poorly developed, fine subangular blocky to single grain; moist friable; clear boundary to

Btk: 7-10"; sandy clay loam; strong brown (7.5YR 5/6); poorly developed, fine to medium subangular blocky to single grain; moist friable; dry slightly hard; abrupt boundary to

IICk: 10" +; Obed till; not sampled.

Table A21.1 Chemical Analysis

Lab. No.	Hor.	pH	%N	%O.C.	C/N	$\%CaCO_3$ Equiv.	Oxalate %FE	Oxalate %Al	Dithionite %Fe	Dithionite %Al
R69317	Bmk	7.8	0.17	2.52	15	0.34	0.64	0.25	0.92	0.09
318	Ae2k	7.8	0.05	0.42	8	0.31	0.13	0.05	0.69	0.08
319	Btk	7.8	0.04	0.28	7	0.46	0.23	0.09	0.92	0.10

Table A21.2 Particle Size Analysis

Horizon	% Sand	% Silt	% Total Clay	% Fine Clay
Bmk	24	62	14	5
Ae2k	45	47	8	3
Btk	67	20	13	8

Table A22 Soils, thin sections, horizons, depth and laboratory number of bulked samples

Thin section no.	Horizon	Depth (inches)	Lab. No.
	Calcareous Brunisolic Gray Luvisol		
D99, D100	Bm1k	0-3	R68589
D101, D102	Bm2k	3-5	590
D103, D104		5-8	591
D105, D106	Ae2k	8-11 1/2	592
D107, D108		11 1/2-16	593
D109, D110		16-20 1/2	594
D111, D112	Btk	20 1/2-24	595
D113, D114		24-27	596
D115, D116		27-30	597
D117, D118	Ck	30-34	598
	Calcareous Brunisolic Moder Gray Brown Luvisol		
D119, D120	Ahk	0-3	R68599
D121, D122		3-6	600
D123, D124	Ahek	6-8 1/2	601
D125, D126		8 1/2-11	602
D127, D128	Bmk	11-14	603
D129, D130		14-16 1/2	604
D131, D132	Ae2k	16 1/2-19	605
D133, D134		19-21	606
D135, D136	Btk	21-24 1/2	607
D137, D138		24 1/2-28	608
D139, D140	Ck	28-32	609
	Calcareous Orthic Moder Melanic Brunisol		
D141, D142	Ah1k	0-2 1/2	R68610
D143, D144	Ah2k	2 1/2-5	611
D145, D146	Bmk	5-7 1/2	612
D147, D148		7 1/2-10	613
D149, D150	Ck	10-13	614
	Calcareous Degraded Moder Melanic Brunisol		
D151, D152	Ahk	0-3 1/2	R68615
D153, D154	Aek	3 1/2-8	616
D155, D156	Bm1k	8-11 1/2	617
D157, D158	Bm2k	11 1/2-15 1/2	618
D159, D160	BC1k	15 1/2-19	619
D161, D162	BC2k	19-23	620
D163, D164	Ck	23-27	621

Table A23. Modal Analysis

(first number is observations, second number is per cent).

Thin Section	Qtz + Feldspar	Skeletal Material: Calcite + Dolomite	Skeletal Material: Siderite	Rock Frag.	Other
		Calcareous Brunisolic Gray Luvisol			
D99	137/33.7	2/0.5	1/0.2	28/6.9	6/1.5
D100	168/42.0	1/0.2	4/1.0	17/4.2	4/1.0
D101	137/34.2	-	-	23/5.8	1/0.2
D102	160/40.0	-	1/0.2	29/7.2	2/0.5
D103	163/40.8	5/1.2	1/0.2	31/7.8	5/1.2
D104	174/43.4	1/0.2	2/0.5	34/8.5	8/2.0
D105	175/43.8	6/1.5	3/0.8	31/7.8	1/0.2
D106	181/45.2	2/0.5	1/0.2	37/9.2	1/0.2
D107	161/40.2	8/2.0	1/0.2	22/5.5	1/0.2
D108	166/41.3	13/3.2	1/0.2	26/6.5	2/0.5
D109	160/40.0	3/0.8	1/0.2	36/9.0	1/0.2
D110	162/40.5	4/1.0	2/0.5	23/5.8	4/1.0
D111	194/48.4	1/0.2	-	30/7.5	4/1.0
D112	189/47.1	1/0.2	-	29/7.2	-
D113	185/46.2	1/0.2	-	37/9.2	1/0.2
D114	177/44.2	-	-	39/9.8	1/0.2
D115	155/38.6	3/0.8	1/0.2	37/9.2	5/1.2
D116	159/39.8	2/0.5	-	36/9.0	2/0.5
D117*	60/15.0	34/8.5	8/2.0	28/7.0	1/0.2
D118	116/29.0	51/12.8	10/2.5	34/8.5	1/0.2
D118	115/28.8	43/10.8	7/1.8	28/7.0	-

* D117 was judged as being non-representative because of the large amount of secondary carbonates. It was not included in final calculations. In its place a repeat count was done on D118.

Table A23. Modal Analysis

(first number is observations, second number is per cent).

Glaeb.[1] + Fe nod.	Plasmic Separations: Free[2] Gr. Cutans	Plasmic Separations: Second.[3] CO_3	Other	Pores: Ortho	Pores: Meta	Organic Frag.
		Calcareous Brunisolic Gray Luvisol				
7/1.7	67/16.5	1/0.2	13/3.2	106/26.1	16/3.9	22/5.4
6/1.5	79/19.8	-	10/2.5	79/19.8	24/6.0	8/2.0
3/0.8	61/15.2	4/1.0	46/11.5	99/24.8	10/2.5	16/4.0
2/0.5	62/15.5	-	56/14.0	64/16.0	17/4.2	7/1.8
10/2.5	50/12.5	2/0.5	16/4.0	114/28.5	1/0.2	2/0.5
15/3.7	39/9.7	9/2.2	6/1.5	105/26.2	-	8/2.0
9/2.2	35/8.8	21/5.2	9/2.2	108/27.0	-	2/0.5
5/1.2	45/11.2	2/0.5	12/3.0	106/26.5	3/0.8	5/1.2
10/2.5	29/7.2	20/4.5	16/4.0	114/28.4	1/0.2	18/4.5
24/6.0	22/5.5	7/1.7	20/5.0	108/26.9	2/0.5	11/2.7
18/4.5	31/7.8	17/4.2	17/4.2	96/24.0	-	20/5.0
22/5.5	30/7.5	13/3.2	27/6.8	105/26.2	-	8/2.0
13/3.2	58/14.5	2/0.5	2/0.5	78/19.4	18/4.5	1/0.2
7/1.8	63/15.7	3/0.8	5/1.2	81/20.2	21/5.2	2/0.5
7/1.8	64/16.0	1/0.2	5/1.2	80/20.0	17/4.2	2/0.5
21/5.2	62/15.5	-	3/0.8	80/20.0	14/3.5	3/0.8
17/4.2	63/15.7	7/1.8	18/4.5	70/17.5	21/5.2	4/1.0
14/3.5	58/14.5	6/1.5	18/4.5	89/22.2	15/3.8	1/0.2
16/4.0	-	157/39.2	11/2.8	84/21.0	1/0.2	-
10/2.5	-	89/22.2	8/2.0	77/19.2	-	4/1.0
10/2.5	-	109/27.2	6/1.5	78/19.5	3/0.8	1/0.2

1. Glaebules + iron nodules.
2. Free Grain Cutans.
3. Secondary Carbonates.

Table A24. Modal Analysis

(first number is observations, second number is per cent).

Thin Section	Qtz + Feldspar	Skeletal Material: Calcite + Dolomite	Skeletal Material: Siderite	Rock Frag.	Other
	Calcareous Brunisolic Moder Gray Brown Luvisol				
D119	84/21.0	39/9.8	5/1.2	5/1.2	2/0.5
D120	82/20.5	62/15.5	5/1.2	8/2.0	3/0.8
D121	99/24.8	50/12.5	4/1.0	7/1.8	2/0.5
D122	94/23.5	41/10.2	4/1.0	10/2.5	3/0.8
D123	79/19.8	44/11.0	4/1.0	13/3.2	1/0.2
D124	81/20.2	47/11.8	3/0.8	12/3.0	3/0.8
D125	75/18.7	39/9.7	4/1.0	10/2.5	4/1.0
D126	92/22.9	34/8.5	2/0.5	12/3.0	-
D127	155/38.9	10/2.5	-	14/3.5	5/1.3
D128	168/41.9	6/1.5	-	17/4.3	2/0.5
D129	184/46.0	5/1.2	-	17/4.2	3/0.8
D130	179/44.8	4/1.0	1/0.2	19/4.8	3/0.8
D131	195/48.8	5/1.2	-	19/4.8	4/1.0
D132	185/46.2	2/0.5	-	18/4.5	7/1.8
D133	182/45.5	2/0.5	1/0.2	21/5.2	6/1.8
D134	196/49.0	2/0.5	1/0.2	16/4.0	5/1.2
D135	132/33.0	3/0.8	-	9/2.2	2/0.5
D136	142/35.5	3/0.8	-	7/1.8	6/1.5
D137	152/38.0	5/1.2	-	18/4.5	10/2.5
D138	149/37.2	2/0.5	-	14/3.5	3/0.8
D139	143/35.8	40/10.0	2/0.5	19/4.8	6/1.5
D140	158/39.5	48/12.0	1/0.2	14/3.5	6/1.5

Table A24. Modal Analysis

(first number is observations, second number is per cent).

Glaeb. + Fe nod.	Plasmic Separations: Free Gr. Cutans	Plasmic Separations: Second. CO_3	Other	Pores: Ortho	Pores: Meta	Organic Frag.
		Calcareous Brunisolic Moder Gray Brown Luvisol				
6/1.5	4/1.0	-	59/14.8	129/32.2	-	67/16.8
6/1.5	5/1.2	-	87/21.8	79/19.8	-	63/15.8
15/3.8	6/1.5	-	87/21.8	70/17.5	-	60/15.0
8/2.0	8/2.0	3/0.8	96/24.0	85/21.2	-	48/12.0
13/3.2	10/2.5	9/2.2	90/22.5	94/23.5	2/0.5	41/10.2
9/2.2	16/4.0	11/2.8	87/21.8	82/20.5	5/1.25	44/11.0
7/1.7	11/2.7	6/1.5	97/24.2	89/22.2	6/1.5	53/13.2
7/1.7	16/4.0	10/2.5	93/23.1	104/25.9	4/1.0	28/7.0
4/0.8	38/9.6	6/1.5	40/10.0	94/23.6	20/5.0	12/3.0
6/1.5	37/9.2	8/2.0	38/9.5	97/24.2	11/2.7	11/2.7
3/0.8	41/10.2	9/2.2	31/7.8	85/21.2	15/3.8	7/1.8
3/0.8	41/10.2	8/2.0	36/9.0	86/21.5	10/2.5	10/2.5
2/0.5	25/6.2	9/2.2	37/9.2	88/22.0	9/2.2	7/1.8
2/0.5	24/6.0	3/0.8	48/12.0	92/23.0	9/2.2	10/2.5
3/0.8	23/5.8	9/2.2	43/10.8	103/25.8	4/1.0	3/0.8
3/0.8	29/7.2	6/1.5	40/10.0	94/23.5	6/1.5	2/0.5
6/1.5	92/23.0	3/0.8	41/10.2	61/15.2	44/11.0	7/1.8
2/0.5	87/21.8	4/1.0	35/8.8	62/15.5	46/11.5	6/1.5
2/0.5	75/18.8	1/0.2	38/9.5	55/13.8	39/9.8	5/1.2
4/1.0	91/22.8	3/0.8	39/9.8	47/11.8	41/10.2	7/1.8
7/1.8	11/2.8	29/7.2	44/11.0	86/21.5	2/0.5	11/2.8
6/1.5	11/2.8	22/5.5	37/9.2	83/20.8	3/0.8	11/2.8

Table A25. Modal Analysis

(first number is observations, second number is per cent).

Thin Section	Qtz + Feldspar	Skeletal Material: Calcite + Dolomite	Skeletal Material: Siderite	Rock Frag.	Other
		Calcareous Orthic Moder Melanic Brunisol			
D141	79/19.8	48/12.0	4/1.0	29/7.2	3/0.8
D142	75/18.7	38/9.5	2/0.5	27/6.7	2/0.5
D143	128/32.0	15/3.8	1/0.2	49/12.2	1/0.2
D144	115/28.8	22/5.5	-	44/11.0	3/0.8
D145	125/31.2	2/0.5	-	71/17.8	4/1.0
D146	128/32.0	5/1.2	-	49/12.2	2/0.5
D147	128/32.0	9/2.2	-	75/18.8	-
D148	121/30.2	9/2.4	2/0.5	78/19.4	3/0.8
D149	117/29.2	49/12.2	11/2.8	66/16.5	1/0.2
D150	123/30.8	53/13.2	3/0.8	82/20.5	2/0.5
		Calcareous Degraded Moder Melanic Brunisol			
D151	64/16.0	12/3.0	-	8/2.0	3/0.8
D152	60/15.0	12/3.0	-	6/1.5	3/0.8
D153	111/27.8	13/3.2	-	23/5.8	3/0.8
D154	113/28.2	13/3.2	1/0.2	18/4.5	4/1.0
D155	140/35.0	1/0.2	-	46/11.5	6/1.5
D156	135/33.8	3/0.8	-	45/11.2	3/0.8
D157	141/35.2	-	-	41/10.2	6/1.2
D158	153/38.2	2/0.5	-	35/8.8	3/0.8
D159	141/35.2	-	-	34/8.5	2/0.5
D160	154/38.5	1/0.2	-	38/9.5	5/1.2
D161	148/37.0	1/0.2	-	64/16.0	2/0.5
D162	152/38.0	5/1.2	-	47/11.8	8/2.0
D163	156/39.0	37/9.2	4/1.0	50/12.5	4/1.0
D164	146/36.5	35/8.8	2/0.5	44/11.0	2/0.5

Table A25. Modal Analysis

(first number is observations, second number is per cent).

Glaeb. + Fe nod.	Plasmic Separations: Free Gr. Cutans	Plasmic Separations: Second. CO_3	Other	Pores: Ortho	Pores: Meta	Organic Frag.
		Calcareous Orthic Moder Melanic Brunisol				
4/1.0	1/0.2	13/3.2	57/14.2	82/20.5	2/0.5	78/19.5
4/1.0	4/1.0	16/4.0	73/18.2	86/21.4	-	74/18.4
3/0.8	20/5.0	13/3.2	78/19.5	58/14.5	6/1.5	28/7.0
11/2.8	19/4.8	12/3.0	80/20.0	66/16.5	5/1.2	23/5.8
3/0.8	49/12.2	4/1.0	47/11.8	66/16.5	24/6.0	5/1.2
6/1.5	47/11.8	2/0.5	60/15.0	57/14.2	34/8.5	10/2.5
2/0.5	36/9.0	8/2.0	39/9.8	59/14.8	29/7.2	15/3.8
-	54/13.5	9/2.2	42/10.5	45/11.2	24/6.0	14/3.5
-	12/3.0	8/2.0	33/8.2	97/24.2	-	6/1.5
1/0.2	12/3.0	6/1.5	29/7.2	81/20.2	-	8/2.0
		Calcareous Degraded Moder Melanic Brunisol				
-	-	18/4.5	75/18.8	141/35.2	-	79/19.8
1/0.2	1/0.2	12/3.0	67/16.8	124/31.0	-	114/28.5
5/1.2	7/1.8	22/5.5	81/20.2	86/21.2	2/0.5	47/11.8
3/0.8	12/3.0	26/6.5	104/26.0	69/17.2	6/1.5	31/7.8
-	66/16.5	8/2.0	47/11.8	62/15.5	21/5.2	3/0.8
-	71/17.8	5/1.2	61/15.2	49/12.2	24/6.0	4/1.0
-	69/17.2	6/1.5	42/10.5	58/14.5	25/6.2	12/3.0
2/0.5	74/18.5	4/1.0	53/13.2	48/12.0	19/4.8	4/1.0
2/0.5	52/13.0	3/0.8	69/17.2	79/19.8	9/2.2	9/2.2
3/0.8	46/11.5	7/1.8	68/17.0	64/16.0	11/2.8	6/1.5
1/0.2	41/10.2	4/1.0	59/14.8	78/19.5	2/0.5	-
1/0.2	30/7.5	5/1.2	66/16.5	80/20.0	1/0.2	5/1.2
-	5/1.2	12/3.0	43/10.8	88/22.0	-	1/0.2
-	8/2.0	24/6.0	49/12.2	79/19.8	-	11/2.8

Table A26. Routine Chemical Analysis on Monolith Profiles

Hor.	Depth (in.)	pH	$\%CaCO_3$ Equiv.	%N	%O.C.	C/N	Oxalate Ext. %Fe	Oxalate Ext. %Al	Dithionite Ext. %Fe	Dithionite Ext. %Al
				Calcareous Brunisolic Gray Luvisol						
Bm1k	0-3	7.5	0.24	0.05	0.65	13	0.15	0.12	0.77	0.03
Bm2k	3-5	7.9	9.26	0.10	1.60	16	0.18	0.16	0.54	0.01
	5-8	7.9	5.12	0.05	0.48	10	0.14	0.06	0.64	0.02
Ae2k	8-11.5	8.0	3.82	0.04	0.41	10	0.22	0.05	0.54	0.02
	11.5-16	8.0	3.43	0.06	0.71	12	0.29	0.19	0.57	0.03
	16-20.5	8.0	1.13	0.03	0.26	9	0.17	0.08	0.56	0.03
Btk	20.5-24	8.0	0.84	0.02	0.16	8	0.14	0.06	0.66	0.04
	24-27	7.8	0.50	0.03	0.18	6	0.18	0.07	0.72	0.06
	27-30	7.8	1.92	0.04	0.25	6	0.26	0.12	0.94	0.04
Ck	30-34	8.2	19.63	0.06	0.88	15	0.15	0.05	0.48	0.02
				Calcareous Orthic Moder Melanic Brunisol						
Ah1k	0-2.5	8.2	12.58	0.26	4.00	15	0.83	0.19	0.86	0.04
Ah2k	2.5-5	8.3	5.60	0.12	1.52	13	0.84	0.19	0.68	0.02
Bmk	5-7.5	8.3	0.88	0.04	0.42	10	0.48	0.30	0.57	0.03
	7.5-10	8.3	6.80	0.04	0.32	8	0.39	0.24	0.47	0.03
Ck	10-13	8.4	19.02	0.04	0.26	6	0.32	0.14	0.36	0.01

Table A26. Routine Chemical Analysis on Monolith Profiles

Hor.	Depth (in.)	pH	%$CaCO_3$ Equiv.	%N	%O.C.	C/N	Oxalate Ext. %Fe	Oxalate Ext. %Al	Dithionite Ext. %Fe	Dithionite Ext. %Al
					Calcareous Brunisolic Moder Gray Brown Luvisol					
Ahk	0-3	7.8	18.91	0.52	7.58	15	0.40	0.12	0.80	0.12
	3-6	8.1	16.81	0.36	5.42	15	0.69	0.22	0.95	0.20
Ahek	6-8.5	8.2	18.38	0.25	2.64	11	0.88	0.23	0.99	0.06
	8.5-11	8.2	8.62	0.10	0.98	10	0.48	0.16	0.74	0.02
Bmk	11-14	8.1	1.20	0.03	0.30	10	0.22	0.06	0.61	0.02
	14-16.5	8.2	0.85	0.02	0.16	8	0.23	0.12	0.68	0.02
Ae2k	16.5-18.5	8.0	0.52	0.02	0.14	7	0.16	0.06	0.71	0.01
	18.5-21	8.2	0.78	0.02	0.13	6	0.16	0.12	0.79	0.02
Btk	21-24.5	8.0	0.65	0.04	0.24	6	0.27	0.16	0.58	0.02
	24.5-28	8.1	1.08	0.04	0.26	6	0.44	0.19	1.27	0.04
Ck	28-32	8.2	18.02	0.05	0.59	12	0.30	0.09	0.65	0.02
					Calcareous Degraded Moder Melanic Brunisol					
Ahk	0-3.5	7.9	10.81	0.43	8.19	19	0.59	0.13	0.76	0.09
Aek	3.5-8	8.2	9.16	0.25	3.56	14	0.82	0.37	1.08	0.07
Bm1k	8-11.5	8.1	0.86	0.04	0.55	14	0.42	0.25	0.58	0.02
Bm2k	11.5-15.5	8.0	0.56	0.03	0.31	10	0.30	0.12	0.61	0.02
BC1k	15.5-19	7.9	0.53	0.03	0.26	9	0.34	0.56	0.70	0.04
BC2k	19-23	8.0	0.60	0.02	0.22	1	0.33	0.12	0.57	0.04
Ck	23-27	8.2	12.47	0.03	0.56	19	0.10	0.06	0.36	0.04

Table A27. Particle Size Analysis on Monolith Profiles

Hor.	Depth (in.)	Sand Sizes as Per Cent of Soil V.C.S.	C.S.	M.S.	F.S.	V.F.S.	% Total Sand	% Silt	% Clay	% Fine Clay
		Calcareous Brunisolic Gray Luvisol								
Bm1k	0-3	0.2	2.6	5.9	20.3	28.9	58	30	12	7
Bm2k	3-5	-	2.4	5.7	19.1	30.4	58	29	13	4
	5-8	0.4	4.2	8.1	21.9	26.4	61	26	12	4
Ae2k	8-11.5	0.2	3.5	8.0	21.2	26.8	60	29	10	4
	11.5-16	0.2	3.2	8.8	22.8	20.4	55	38	8	2
	16-20.5	0.2	3.4	8.3	23.7	22.8	58	32	10	5
Btk	20.5-24	0.1	2.2	5.1	20.4	32.0	60	28	12	6
	24-27	0.2	2.4	5.7	18.8	31.4	59	28	13	8
	27-30	0.1	2.9	6.5	16.3	21.8	48	36	16	10
Ck	30-34	0.3	5.9	8.9	16.6	20.2	52	38	10	6
		Calcareous Orthic Moder Melanic Brunisol								
Ah1k	0-2.5	0.7	3.3	5.6	15.4	18.0	43	42	15	6
Ah2k	2.5-5	0.6	6.4	10.8	24.9	12.3	55	29	16	6
Bmk	5-7.5	3.3	14.9	19.9	37.3	15.2	91	5	4	3
	7.5-10	3.3	17.4	22.3	33.9	7.9	85	7	8	5
Ck	10-13	1.8	9.6	11.1	47.7	14.8	85	12	3	2

Table A27. Particle Size Analysis on Monolith Profiles

Hor.	Depth (in.)	Sand Sizes as Per Cent of Soil V.C.S.	C.S.	M.S.	F.S.	V.F.S.	% Total Sand	% Silt	% Clay	% Fine Clay
		Calcareous Brunisolic Moder Gray Brown Luvisol								
Ahk	0-3	0.1	0.4	0.4	4.5	22.5	28	66	6	2
	3-6	0.1	0.4	0.4	4.3	21.1	26	66	7	3
Ahek	6-8.5	0.1	0.4	0.6	8.2	17.5	26	64	10	2
	8.5-11	-	0.3	1.6	27.2	28.2	58	36	6	2
Bmk	11-14	-	0.2	2.1	33.4	35.6	72	24	5	2
	14-16.5	-	0.3	2.5	36.2	35.6	75	20	5	2
Ae2k	16.5-18.5	-	0.2	1.2	27.3	44.5	74	22	4	2
	18.5-21	0.1	0.1	0.6	19.5	47.2	68	26	7	2
Btk	21-24.5	0.1	0.1	0.2	13.8	40.4	55	30	14	8
	24.5-28	-	0.1	0.2	11.5	38.4	50	37	12	5
Ck	28-32	0.2	0.3	0.6	16.1	42.0	60	34	6	4
		Calcareous Degraded Moder Melanic Brunisol								
Ahk	0-3.5	-	1.5	2.8	15.3	23.8	44	45	11	4
Aek	3.5-8	0.1	1.2	2.1	7.1	13.4	24	70	6	6
Bm1k	8-11.5	0.2	2.4	6.8	24.0	24.2	58	36	7	5
Bm2k	11.5-15.5	0.1	2.6	6.8	23.9	28.0	62	31	7	6
BC1k	15.5-19	0.1	1.8	6.4	24.2	27.6	60	32	8	8
BC2k	19-23	-	2.9	11.0	35.4	24.4	74	16	10	6
Ck	23-27	0.1	5.8	16.2	34.4	23.2	80	12	8	4

Table A28. Estimated Clay Mineral Contents[a].

Horizon	Depth (in.)	Coarse Clay (2.0-0.2μ) Mt[b.]	Ch[c.]	Ill[d.]	Ka[e.]	Qtz[f.]	Fine Clay (<0.2μ) Mt[b.]	Ill[d.]	Qtz[f.]
		Calcareous Orthic Moder Melanic Brunisol							
Ah1k	0-2.5	H	M	M	L	L	H	L	L
Ah2k	2.5-5	H	M	M	L	M	H	L	L
Bmk	5-7.5	H	M	M	L	M	H	L	L
	7.5-10	H	M	M	L	M	H	L	L
Ck	10-13	M	M	M	L	M	H	L	L
		Calcareous Degraded Moder Melanic Brunisol							
Ahk	0-3.5	M	M	M	L	L	H	L	L
Aek	3.5-8	M	M	M	L	M	H	L	L
Bm1k	8-11.5	M	M	M	L	M	H	L	L
Bm2k	11.5-15.5	M	M	M	L	M	H	L	L
BC1k	15.5-19	H	M	M	L	M	H	L	L
BC2k	19-23	H	M	M	L	M	H	L	L
Ck	23-27	H	M	H	M	M	H	L	L

a. Expressed in relative proportions as follows:
L - Low (20%); M - Medium (20-50%); H - High (50%)

b. Montmorillonite

c. Chlorite - 14 A° peak after 550° C

d. Illite - 10 A° peak after glycolation

e. Kaolinite - 7 A° peak disappears after 550° C

f. Quartz - Estimated using 4.26 A° peak.

Table A28. Estimated Clay Mineral Contents[a.]

Horizon	Depth (in.)	Coarse Clay (2.0-0.2μ) Mt[b.]	Ch[c.]	Ill[d.]	Ka[e.]	Qtz[f.]	Fine Clay (<0.2μ) Mt[b.]	Ill[d.]	Qtz[f.]
				Calcareous Brunisolic Moder Gray Brown Luvisol					
Ahk	0-3	L	L	M	L	L	H	M	L
	3-6	L	M	M	L	L	H	M	L
Ahek	6-8.5	L-M	M	M	L	L	H	M	L
	8.5-11	M	M	M	L	L	H	M	L
Bmk	11-14	L-M	M	M	L	M	H	M	L
	14-16.5	L-M	M	M	L	M	H	M	L
Ae2k	16.5-19	M	M	M	L	M	H	L	L
	19-21	M	M	M	L	M	H	L	L
Btk	21-24.5	L	M	M	L	M	H	L	L
	24.5-28	L	M	M-H	L	L	H	L	L
Ck	28-32	L	M	M	L	L	H	M	L
				Calcareous Brunisolic Gray Luvisol					
Bm1k	0-3	M	M	M	L	M	H	L	L
Bm2k	3-5	M	M	M	L	M	H	L	L
	5-8	M	M	M	L	M	H	L	L
Ae2k	8-11.5	M	M	M	L	M	H	L	L
	11.5-16	M	M	M	L	M	H	L	L
	16-20.5	M	M	M	L	M	H	L	L
Btk	20.5-24	M	M	M	L	M	H	L	L
	24-27	H	M	M	L	M	H	L	L
	27-30	H	M	M	L	M	H	L	L
Ck	30-34	M	M	M	L	M	H	L	L

Table A29. Calculated* Illite and Montmorillonite contents of the Clay Fractions (percentage by weight)

	Hor.	Depth (in.)	K20 (%)	Surface Area (m.2/g.)	Illite (%)	Montm. (%)
			Calcareous Orthic Moder Melanic Brunisol			
Fine Clay (<0.2μ)	Ah1k	0-2.5	3.35	666	35	65
	Ah2k	2.5-5	2.43	685	25	70
	Bmk	5-7.5	2.41	803	25	80
		7.5-10	2.60	793	25	80
	Ck	10-13	2.87	727	30	70
			Lower Solum and Ck of the Calcareous Brunisolic Moder Gray Brown Luvisol			
	Bmk	11-14	3.62	502	35	50
		14-16.5	3.64	495	35	50
	Ae2k	16.5-19	3.74	457	35	45
		19-21	4.03	499	40	50
	Btk	21-24.5	4.33	461	45	50
		24.5-28	4.25	446	40	45
	Ck	28-32	4.53	532	45	55
			Calcareous Orthic Moder Melanic Brunisol			
Coarse Clay (2.0-0.2μ)	Ah1k	0-2.5	3.83	302	40	30
	Ah2k	2.5-5	3.12	377	30	40
	Bmk	5-7.5	3.25	316	30	30
		7.5-10	3.34	400	35	40
	Ck	10-13	3.48	281	35	30
			Lower Solum and Ck of the Calcareous Brunisolic Moder Gray Brown Luvisol			
	Bmk	11-14	4.01	152	40	15
		14-16.5	4.13	162	40	15
	Ae2k	16.5-19	4.22	109	40	10
		19-21	4.21	174	40	15
	Btk	21-24.5	4.38	149	45	15
		24.5-28	4.51	182	45	20
	Ck	28-32	4.47	195	45	20

* Calculated to the nearest 5 per cent

Table A30. Percentage Estimates (by weight) of the Fine Sand Fraction According to Varying Specific Gravities

Horizon	Depth (in.)	%< 2.40	% 2.40-2.96	%> 2.96
	Calcareous Orthic Moder Melanic Brunisol			
Ah1k	0-2.5	0.67	97.98	0.63
Ah2k	2.5-5	2.11	95.50	0.73
Bmk	5-7.5	1.19	97.81	0.77
	7.5-10	0.33	97.64	1.07
Ck	10-13	0.67	98.14	1.03
	Calcareous Brunisol Moder Gray Brown Luvisol			
Ahk	0-3	2.21	94.78	0.55
	3-6	3.39	93.42	0.49
Ahek	6-8.5	0.17	98.36	0.63
	8.5-11	0.63	96.24	0.99
Bmk	11-14	0.51	97.56	1.11
	14-16.5	0.03	97.88	1.15
Ae2k	16.5-18.5	0.03	97.34	1.15
	18.5-21	1.05	96.26	1.33
Btk	21-24.5	0.27	97.68	0.75
	24.5-28	0.64	97.98	0.92
Ck	28-32	0.29	98.64	0.81
	Calcareous Degraded Moder Melanic Brunisol			
Ahk	0-3.5	3.11	94.36	0.39
Aek	3.5-8	1.08	98.16	0.32
Bm1k	8-11.5	0.19	98.62	0.75
Bm2k	11.5-15.5	1.29	97.12	0.75
BC1k	15.5-19	0.81	98.18	0.63
BC2k	19-23	0.37	98.06	0.73
Ck	23-27	1.07	97.98	0.63
	Calcareous Brunisol Gray Luvisol			
Bm1k	0-3	0.83	98.28	0.49
Bm2k	3-5	0.37	98.58	0.55
	5-8	1.25	98.53	0.61
Ae2k	8-11.5	0.33	98.84	0.51
	11.5-16	1.31	97.74	0.55
	16-20.5	0.21	99.20	0.49
Btk	20.5-24	0.83	98.52	0.43
	24-27	0.27	98.90	0.51
	27-30	0.33	98.64	0.53
Ck	30-34	1.07	97.62	0.65
Reference		0.13	98.22	0.77

Table A31. Percentage Estimates of very Light Minerals (s.g. <2.40) as a Function of Total very Light Mineral Content

Hor.	Volc. Glass	Volc. Frag.	Quartz	Rock Frag.	Min. Roots	Carb.	Wood Frag.	Other
			Calcareous Orthic Moder Melanic Brunisol					
Ahk	4.7	2.0	33.5	5.7	21.4	-	21.4	12.5
Bmk	1.0	2.2	61.0	22.3	1.9	4.1	3.9	3.6
Ck	4.4	2.7	42.7	21.5	2.5	0.7	22.2	3.2
			Calcareous Degraded Moder Melanic Brunisol					
Ahk	2.9	0.6	25.8	2.2	38.7	-	11.6	18.1
Aek	3.2	1.3	43.0	1.9	8.9	-	28.3	13.4
Bmk	9.4	6.2	48.9	13.3	5.9	-	8.9	7.6
BCk	0.2	1.2	68.2	23.1	0.2	-	5.7	1.5
Ck	2.0	2.7	72.6	20.0	0.5	-	2.0	0.2
			Calcareous Brunisol Moder Gray Brown Luvisol					
Ahk	0.7	0.7	23.6	-	27.7	0.7	32.8	17.2
Ahek	12.2	10.2	27.2	-	9.5	8.7	19.2	8.5
Bmk	3.9	3.7	77.5	7.4	1.0	2.0	3.7	1.2
Ae2k	1.5	1.5	80.2	9.4	0.7	0.2	5.7	1.0
Btk	0.7	1.0	71.4	12.8	4.0	-	7.4	2.7
Ck	0.2	1.0	66.7	14.9	3.5	0.5	10.4	3.0
			Calcareous Brunisol Gray Luvisol					
Bmk	1.0	6.0	59.6	14.9	6.0	-	9.7	3.7
Ae2k	28.2	12.3	34.6	5.2	5.6	0.2	8.6	5.9
Btk	0.2	6.4	72.4	14.1	3.7	-	1.5	2.0
Ck	68.9	2.2	6.5	1.5	7.7	-	9.0	4.2
Reference								
	6.5	1.0	25.1	2.0	-	63.7	1.5	0.7

Table A32. Percentage Estimates of Light Minerals (s.g. 2.40-2.96) as a Function of Total Light Mineral Content

Hor.	Quartz	Ortho.	Plagio.	Chert	Rock Frag.	Carb.	Mica.	Other
				Calcareous Orthic Moder Melanic Brunisol				
Ahk	70.4	10.4	0.7	5.5	10.6	1.0	-	1.3
Bmk	63.9	11.3	1.2	7.9	13.8	-	-	2.2
Ck	64.3	9.1	0.7	6.9	17.2	0.2	-	1.5
				Calcareous Degraded Moder Melanic Brunisol				
Ahk	58.7	9.6	0.5	5.1	10.3	0.2	1.6	14.0
Aek	68.1	9.9	0.2	4.7	12.1	1.0	-	4.0
Bmk	68.9	9.3	0.9	6.1	13.3	-	-	1.4
BCk	68.1	11.3	0.2	6.2	12.2	-	-	2.4
Ck	67.8	12.3	0.3	7.3	11.3	0.8	-	0.3
				Calcareous Brunisol Moder Gray Brown Luvisol				
Ahk	63.9	7.0	0.2	3.5	13.4	3.7	0.7	8.2
Ahek	73.9	7.6	0.2	3.6	13.3	0.5	-	1.4
Bmk	73.7	8.3	0.2	5.0	11.6	1.2	-	0.2
Ae2k	78.4	6.9	0.7	3.2	10.3	0.2	-	0.2
Btk	71.8	6.4	0.5	6.1	13.2	2.7	-	-
Ck	75.6	7.8	0.5	2.4	12.5	0.7	-	0.5
				Calcareous Brunisol Gray Luvisol				
Bmk	74.1	14.4	0.2	3.4	7.2	0.2	-	0.5
Ae2k	73.1	10.6	0.5	2.7	11.6	0.5	-	1.0
Btk	65.4	12.3	-	6.3	14.8	0.2	0.2	0.7
Ck	69.8	11.2	0.7	3.7	12.2	-	1.0	1.2
Reference								
	40.0	4.7	0.5	6.9	10.9	36.0	-	1.0

Table A33. Percentage Estimates of Heavy Minerals (s.g.>2.96) as a Function of Total Heavy Mineral Content

Horizon	Chlorite	Garnet	Epidote	Amphibole	Mica	Volcanic Fragment
			Calcareous Orthic Moder Melanic Brunisol			
Ahk	13.2	3.7	5.2	1.5	1.0	0.5
Bmk	8.3	5.3	3.0	-	0.8	1.0
Ck	9.0	2.5	3.5	1.0	0.5	1.0
			Calcareous Degraded Moder Melanic Brunisol			
Ahk	12.9	4.0	6.5	2.0	2.5	2.5
Aek	16.6	4.5	9.5	4.0	6.5	1.5
Bmk	9.6	4.0	4.2	2.7	0.7	1.7
BCk	7.1	4.4	3.4	1.2	2.2	2.0
Ck	10.3	3.9	7.4	1.5	2.4	2.0
			Calcareous Brunisolic Moder Gray Brown Luvisol			
Ahk	20.3	2.9	12.2	0.7	4.4	1.7
Ahek	15.9	4.3	10.3	1.2	3.1	2.2
Bmk	16.4	3.6	9.3	1.0	2.1	1.0
Ae2k	13.8	2.8	7.3	0.8	2.0	2.0
Btk	15.6	4.0	8.4	0.5	2.7	1.2
Ck	11.4	3.5	6.5	0.5	2.0	1.5
			Calcareous Brunisolic Gray Luvisol			
Bmk	15.5	4.2	6.0	0.5	1.5	1.0
Ae2k	10.1	4.4	5.4	0.5	1.5	1.2
Btk	11.0	3.5	5.0	0.2	1.2	2.0
Ck	9.9	3.5	3.5	0.5	1.5	1.0
Reference	21.1	-	11.8	2.9	2.4	3.9

Table A33. Percentage Estimates of Heavy Minerals (s.g.> 2.96) as a Function of Total Heavy Mineral Content

Zircon	Tourmaline	Rutile	Fe Opaque	Other Opaque	Others
Calcareous Orthic Moder Melanic Brunisol					
10.4	8.4	1.2	45.6	4.0	5.2
12.3	7.0	1.2	51.9	5.3	4.0
10.1	5.5	2.5	55.3	4.0	5.0
Calcareous Degraded Moder Melanic Brunisol					
11.4	7.0	1.5	41.8	2.5	5.5
12.1	8.5	2.0	30.7	2.5	1.5
9.6	5.9	1.5	49.8	5.9	4.2
5.6	6.4	1.7	55.9	6.6	3.4
6.9	8.3	1.5	44.6	7.4	3.9
Calcareous Brunisolic Moder Gray Brown Luvisol					
5.4	8.1	0.5	36.0	3.9	3.7
6.7	5.8	1.2	41.3	6.2	1.7
8.8	9.0	0.7	40.2	5.2	2.6
6.5	7.6	0.8	46.1	7.8	2.5
6.4	8.9	0.5	41.6	7.4	2.7
8.0	8.0	0.5	47.8	6.0	4.5
Calcareous Brunisolic Gray Luvisol					
6.5	10.2	1.2	45.9	5.5	2.0
5.9	6.6	1.5	53.6	6.9	2.4
6.2	8.5	1.2	52.6	5.7	2.7
4.0	12.4	1.0	53.0	5.4	4.5
Reference					
8.3	10.3	1.5	19.1	4.4	10.3

Table A34. Bacterial, Actinomycete, and Fungl contents[1.] in Particular Ahk Horizons

Sample	Bacteria[2.] per gram/air dry	Actinomycetes[2.] per gram/air dry	Fungi[3.] per gram/air dry
R68599	2.6×10^6	9×10^6	750
R68601	3.3×10^6	2×10^6	100
R68610	3.4×10^6	2×10^6	2500
R68611	3.2×10^6	2×10^6	2400
R68615	42×10^6	1×10^6	63,000

1. Plate counts and identification by Dr. F. D. Cook.

2. Bacteria and actinomycetes were grown by spreading 1/10 ml. dilution over prepoured Plate Count agar, and incubating at room temperature for 14 days. Actinomycetes were identified by colony on the same plate.

3. Fungi were grown by spreading 1/10 ml. dilution over Rose Bengal - Streptomycin agar, and incubating at room temperature for 10 days. Genera identified included Penicillium, Aspergillus, Fusarium, Alternaria, and Homodentron.

SOIL MAP OF THE CALCAREOUS LOESS AREA IN THE ATHABASCA RIVER VALLEY

SCALE: 1 INCH = 1 MILE

LEGEND

TOPOGRAPHIC CLASSES

TOPOGRAPHY	% SLOPE
a	0 - 0.5
b	0.5 - 2
c	2 - 5
d	6 - 9
e	10 - 15
f	16 - 30
g	30 - 60
h	>60

SOIL LEGEND

ORDER	GREAT GROUP	TENTATIVE SUBGROUP NAMES	SYMBOL	COLOR
Luvisolic	Gray Luvisol	Calcareous Brunisolic Gray Luvisol	1a	
	Gray Brown Luvisol	Calcareous Brunisolic Moder Gray Brown Luvisol	2a	
Brunisolic	Eutric Brunisol	Calcareous Orthic Eutric Brunisol	3a	
		Calcareous Degraded Eutric Brunisol	3b	
	Melanic Brunisol	Calcareous Orthic Moder Melanic Brunisol	4a	
		Calcareous Degraded Moder Melanic Brunisol	4b	
Regosolic	Regosol	Calcareous Orthic Regosol	5a	
		Calcareous Cumulic Regosol	5b	

MISCELLANEOUS SOILS

Gleysolic and Organic Soils	6a	
Eroded Stream Channels	7a	
Alluvial Soils	8a	
Disturbed Land	9a	
Open Water	10a	

Mapping modifications: /t - till within 30 cm. Lower solum formed in till material
/c - clay material within 30-50 cm
/s - gravel material within 30-50 cm

Each map symbol consists of: $\frac{\text{Dominant Soil + Associated Soil}}{\text{Texture of B horizon, Topographic Class}}$

TOPOGRAPHIC CROSS-SECTIONS WITH ASSOCIATED SOIL DISTRIBUTION

HORIZONTAL SCALE: 1 INCH = 1 MILE
VERTICAL SCALE: 1 INCH = 610 FEET